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THE GLACIAL SUCCESSION IN NORWAY.

As SCANDINAVIA was unquestionably the chief center of the great North European glaciation, it follows that Norway is a country of glacial denudation rather than of glacial deposition. A complete apprehension of its Quaternary history is, therefore, not possible solely through the study of the deposits. The great marks of erosion are to be taken into consideration. We thus come immediately upon the great problem: How far are we to go in our acceptance of glacial erosion? It is of course impossible here to enter into the whole vexed question. It is, however, necessary to briefly summarize some of the reasons which lead the geologist in Norway to admit an erosion of so great degree, that both our fjords and lakes fall wholly within its limits. The most convincing argument is, perhaps, the fact that the great North European diluvial plain contains Scandinavian detritus in such immense quantity that the rock basins in Scandinavia could be refilled and replenished many times with it. A. Helland has calculated that the German and Russian diluvial sheet could fill not only the Scandinavian lakes, but also the Baltic, and still heighten the whole peninsula 25 metres (80′). And besides, we have the enormous quantity of Norwegian rock detritus which forms the bottom of the North Sea and the broad submarine plateau to the west of northern Norway. Even if this estimate is not entirely correct, it is impossible to deny that such enormous quantities of drift have been removed from Norway in Quaternary time that we must look for marks of denudation of quite as great degree as our lakes and fjords.

An estimate of the volume of rock matter which is carried by the glacial rivers of Greenland and Norway proves also that the glacier denudation in a few thousand years must reach great dimensions.

When thus the capacity of the rock basins comes short of holding the known glacial sediment (the quantitative element), the form of the basins (the qualitative element) is quite in harmony with those we find in other glaciated countries and *nowhere else*. Both the lakes and the fjords have a distinguishing trough shape, with flat bottoms and comparatively steep sides, in the transverse section, and, in the longitudinal section, a gradual deepening toward a point that is situated not very far from the outer end, against which it more suddenly shoals up. This form cannot be generated by any other possible eroding agent than glacier ice. The fissure theory is out of the question, as exact sections specifically show. Faults and dislocations cannot account for their specific form and their relations to quite superficial topographical features. The admirable monograph on the Kristiania fjord, by Professor W. C. Brögger, makes it also quite clear that its distinguishing fjord character can only be of glacial origin. Basins of this form, as is well known, are restricted to glaciated countries; and they can be deduced directly from the motion of the eroding glacier. The movement must accelerate towards the point where the ice surface intersects the snow line, where the surplus ice from the whole glacier must pass. Thence it must slacken because of the melting farther down. The erosion, which naturally must depend both on the movement and the pressure of the ice, will decrease accordingly. In this we find the explanation both of the longitudinal form of the glacial basins, and of their evident dependence on the margin of the land ice.

So much may be said about glacial erosion by way of introduction before entering into the study of the succession of glacial events in Norway. We must be somewhat prepared to face the greatness of the phenomena, which only glacial studies can make more familiar to us.

When we try to realize the appearance of Norway in *pre-*

glacial time,—*i. e.*, before the Quaternary age—we have not much on which to base our ideas. The immense denudation has so thoroughly altered the physiognomy of the country that we are quite at a loss to reconstruct it. We can only suppose that no great change in the relative heights of the mountain plateaus has taken place and that there are left, perhaps, in the mountain bosses remnants of the original surface. The coast line we are no doubt justified in putting farther outwards than now. The great slope to the ocean deep does not follow the present coast, but is up to 200 kilometers distant, the intervening bank not reaching beyond 400 meters. The flora and fauna of Spitzbergen and Iceland must have immigrated across this now sunken northwestern foreland. Near Storeggen (about 62°) G. O. Sars found, by dredging at 100 to 200 fathoms (200 to 400M.), remains of a littoral fauna and beach shingle, which can only belong to a preglacial coast. It must therefore be a legitimate inference that the country in late preglacial times was, at least at the coast, 200 to 400 meters higher than now.

On the mountains in this high country there now began to gather great snow masses, the climate deteriorating owing to causes that cannot be treated here.[1] The névés gradually coalesced and the glaciers flowed down to the lower land. If the present numerous fjords had a preglacial existence they must have represented themselves as a close series of deep lakes or fjords into which the glacier soon crept. But beyond such a row of ready outlets no continuous ice margin could possibly grow. The depth of Sognefjord is 1,250 meters, of Hardangerfjord 800 meters, though both are rather shallow at their mouth. If the whole country was elevated 200 to 400 meters, we still would have so deep waters, that any glacier, which could not at once move forward with a thickness of 1,000 meters, would get afloat and be dissolved into icebergs as fast as it could grow. So any advance of inland ice (which necessarily increases but slowly) must

[1] I have given my reasons for accepting a shifting of the pole as cause of the ice ages in a paper: Strandlinje-studier in Archiv for Mathematik og Naturvidenskab Kristiania, 1890–91, T. 9–10.

needs be impossible farther out than at the innermost fjord heads The greatest distance between the heads of any two neighboring fjords on the whole Norwegian coast is only about 60 kilometers (less than 40 miles), and an ice stream driven out over this neck between Sognefjord and Nordfjord could not by any means reach a height of 510 meters at the isles in the mouth of Sognefjord, where we find glacial grooves and foreign boulders 1,760 meters, 5,700 feet above the fjord bottom. With only 20 to 30 kilometers to discharging outlets on each side, its thickness would ever be small. The fact must be kept in view that the inland ice behind, from which the ice stream flowed, had only a very inconsiderable breadth. The distance from the fjord heads to the present watershed is nowhere more than 30 kilometers, and the want of boulders transported from the country more to the east proves that the ice-shed, the glacial divide at the glacial period, could not have been situated far from the watershed. Now a névé less than 30 kilometers broad could never have pushed a continuous margin beyond a close set row of deep fjords. As we now in southern Norway actually find the whole west coast, except the highest points, very strongly glaciated, we are forced to admit that the only state of things in which the ice could have advanced so far west is to be found in a country where depressions, of a volume in any degree comparable with the present fjord system, are wanting. We are obliged to ascribe the formation of our fjords to Quaternary forces—that is, glacial erosion.

We know that boulders from the Kristiania fjord are found in the till as far away as North Netherlands and at Holderness, in England. We further know that the east-going ice flow in Scotland was turned back in Sutherland and that Orkney and Shetland were glaciated from the east, *i. e.*, from Norway. A continuous inland ice could not have grown gradually across the deep Norwegian channel, which encircles southern Norway, the deep sea basin reaching 900 meters. As in the case of the fjords, we must also conclude that this fjord-like basin (which indeed does not reach the depth of some of the fjords) did not exist in preglacial times, but owes its origin to the ice stream that flowed

outwards in it, following the line of least resistance for the ice overflow in central Scandinavia. This only need be 1,500 meters thick to be able to erode the bottom when the maximum erosion was in progress. This ice stream turned round the Naze and left its bottom moraine also on the southwestern Norwegian coastland, *e. g.*, on Jaederen, where boulders from the Kristiania territory are very numerous.

While the extreme eastern margin of the first great inland ice, as demonstrated by the extension of the boulder clay, reached to Kiew and Petschora, we must thus place the western margin at the steep slope to the Norway deep in the North Atlantic Ocean. But we have reason to think that it did not remain there for a very long time. As the weight of the ice increased the land was obliged to *sink* below it. This follows not only from the general physics of the earth's crust as demonstrated by O. Fisher, but can also be directly deduced from facts observed in all former glaciated countries. Invariably when there comes an inland ice there follows a depression; with the melting of it there is everywhere a re-upheaval; and everywhere the amplitude of the crust motion is in close accord with the thickness of the ice sheet.[1] Under the great first inland ice, Norway sank and therewith came a raising of the snow line in relation to the ice surface and an aggression on the ice from the rising sea. Under these circumstances the ice margin was forced back, and many things indicate that it at length took up its position at about the present coast line and paused there while the great terminal glaciers flowed down preglacial depressions and made new ones and scooped out, by long continued action, our grand fjords. Judging from their form and great dimensions, this erosion took place under very constant circumstances. The ice must have kept its place for a very long period constituting, in all probability, the greater part of the first great ice age. It might be objected that when the ice receded by the sinking of the land, the crust upheaval must have followed immediately. As the sea with its

[1] This I have followed out from the known glaciated countries in my Strandlinje-studier, but cannot in this place re-state it more fully.

greater specific gravity in a great degree replaced the melting ice margin, the consequence appears to have been that the land finally lost in height perhaps as much as 200 to 400 meters. We shall find analogous phenomena in other glaciated countries.

The thickness of the inland ice in Norway at this time we are able to estimate by the upper limit of foreign boulders and by the lower limit of the rocks on mountain summits which were not reached by the ice sheet. Where a great continuous scoring ice sheet has worked we find in Norway, as in Greenland and elsewhere, the smooth undulating surface lines with fresh rock surfaces. Higher up, above the reach of ice, we find the *nunatak* formation with peaks and cirques (botner) and with highly weathered rocks and mighty talus and other debris. By such limits we can approximately determine that the maximum height of the ice sheet in southern Norway was below 2000 meters, in northern Norway about 1200 to 1500 meters, these being reckoned from the present sea level. As the mean height of the Norwegian highland may be estimated at 800 to 1000 meters, and as only central Norway reaches more than 1200 meters, we get an ice sheet which, near its axis, will measure only about 800 to 1000 meters. To this thickness of the ice the depression of the land answers very well according to O. Fisher's theory.

The first great Quaternary glaciation of Norway was followed by other great climatic changes. To get a more handy terminology than the common periphrastic nomenclature, I have proposed, for the most pronounced periods, the names *proteroglacial* for the earlier great ice age as distinguished from the well-known last great glaciation that followed—the *deuteroglacial*. I have chosen and press for acceptance at the Congress terms implying the first and the second of *two* periods because these two glaciations seem to be demonstrable for all glaciated countries. The names cannot well be misunderstood, and if, perchance, as some American and German geologists assume, a third separate glaciation can be proved, it will be easy to give it a name apart. So far we can only distinguish in Norway preglacial, proteroglacial,

interglacial, deuteroglacial, and postglacial periods, all very clearly denoted by these names.

The proteroglacial period came at last to an end. The ice retired very much; an interglacial period followed. Of this warmer period we know very few certain traces in Norway. Almost every deposit referable to it has been swept out by the last —the deuteroglacial—ice sheet at least in the parts best studied. At Jaederen we certainly have some layers of gravel and sand between the undermost bottom moraine carrying boulders from the Kristiania territory, and the uppermost one bearing boulders from the mountains close by on the east, but these layers do not contain, as far as known, any fossils giving information about the climate, and it may very probably be that they must be referred to the retiring proteroglacial or the advancing deuteroglacial ice.

The part of the proteroglacial country which was not covered by the deuteroglacial ice sheet or sea—and which, therefore, might have retained interglacial deposits—is very poor in loose matter and it has, as yet, not been possible to distinguish any interglacial debris. In the center of the country at Våge, near the highest mountains in Norway, there was some years ago found in river gravel a molar of the mammoth. It may now be said, that this tooth is certainly neither postglacial, protero- nor deuteroglacial, as the tract in these periods was quite ice-covered. There remains the assumption that it is preglacial or interglacial, and as it is not very probable that this molar has remained unmolested through the very long first glaciation by which the whole country was deeply eroded, it is perhaps permissible to take it for interglacial. In this case we may conclude that the country in interglacial time was covered with forest up to the highest plateaus; and, therefore, the *proteroglacial inland ice was entirely gone.*

It is, however, more reliable to seek for support by a comparison with neighboring countries. The peats in parts of Denmark not deuteroglaciated show an arctic flora with *Dryas, Salix polaris, herbacea,* and *reticulata,* which followed the great retreating proteroglacial ice sheet, and this was superseded by a vegetation char-

acterized by *Populus tremula*, and this again by a *Pinus sylvestris* flora.

Above the layer with Pinus comes a new one with oak and finally the surface stratum with recent forest trees. Now in the peats of deuteroglaciated Norway and Sweden we always find the oak layer on the bottom (with a layer of pine and birch above), which shows, without doubt, that the preceding vegetations in Denmark and Scania must be interglacial. To judge from the aspen and pine forests it might be concluded that the interglacial climate in Scandinavia was somewhat colder than the present, but the melting of the ice may have required a higher temperature and the fossils from layers between the two bottom moraines in the Baltic countries bear a rather southern stamp.

We come to more reliable ground when we advance to the last great glaciation in the *deuteroglacial period*. Again the snow gathered on the high mountain plateaus, again glaciers pushed forward towards the lower ground accompanied by a severe climate. But the glaciers this time were met almost at the watershed by the deep proteroglacial fjords which necessarily must put an end to their advance westward. The continuous western ice margin could not reach beyond the fjord heads. To the east, however, the way was free for the growing inland ice. The consequence of this was that the *ice sheet* divide crept eastwards and reached a line up to 130 kilometers southeast of the land watershed. Here at last the resistance to the glacier motion was alike on both sides of it. *We therefore find the boulders in deuteroglacial time* —in contrast to the distribution in proteroglacial time—*transported across the watershed from lower ground in southeastern central parts* up hundreds of meters to the divide and borne on as far west as the deuteroglacial ice and its icebergs went.

To the west we find the ice margin determinated by the fjords, to the east it pushed forward out to the coast line by Skagerak. We find its margin, as in the case of the deuteroglacial ice in North America, marked by a long terminal moraine—raerne—from Arendal to the Kristiania fjord and thence to southeastern Sweden.

Also in Finland we find a terminal moraine near the south coast. But through this terminal moraine there crept out a very long Baltic ice tongue which reached down to Brandenburg and the eastern part of Schleswic. Behind the terminal moraine in Norway we find a series of lakes eroded, here as elsewhere, near the ice margin, but these lakes are rather small and have no relation to the present valleys behind. It is therefore reasonable to suppose that the inland ice did not have any very considerable thickness here when it reached this extreme limit and also that the valleys were not yet fully developed.

As in proteroglacial time, the country again sank under the ice weight and again the ice sheet retreated with the relative raising of the snowline, and advance of the sea. The retreat is near Kristiania fjord marked by three or four discontinuous moraine lines with, in places, rather large lakes behind (Oiern, Tyrifjord, Norsjö). But in Norway—as in America—a final position was not reached before the great marginal glacier was settled in what was to become a fine row of great lake basins: Solör (filled up), Mjösen, Randsfjord, Sperillen, Kröderen, etc. This most constant phase of the deuteroglacial time deserves a particular name. I have called it the *Epiglacial* epoch, as it closes the great glacial series. It is parallel to the American Champlain epoch, but as American geologists (Dana especially) regard the Champlain epoch as postglacial, I have not ventured to accept the name.

In southeastern Norway we find the terminal glaciers ending in the greatest lake basins in the country; in western and northern Norway the glaciers were, as above explained, stopped by the fjord heads. But here we also find that the glacier ends everywhere once occupied smaller but yet deep lakes, with bottoms often below the sea level, just behind the fjord heads. When we in Norway have more than 100 such lakes cut in the rock just where the glaciers terminated, I cannot see how it is possible to evade the conclusion that these lakes must be of glacial origin. It will not do to suppose that this coincidence of so many lakes and glacier ends is the merest accident. The relation must needs be genetic. The form of the lakes is the typical trough with a longi-

tudinal section in the best accordance with the probable distribution of the erosive power in a glacier.

The rock matter which was scooped out by the epiglacial glaciers was deposited partially as terminal moraines, but mostly as terraces in the fjords. We therefore now find the epiglacial lakes everywhere separated from the fjord heads by some kilometers of terrace land. These great upper terraces mark the level of the epiglacial sea. Their height differs very much in the different districts, and it was first by the study of the corresponding ancient sea beaches that I was able to find the correlation between them. In western and northern Norway, these ancient sea margins are very distinctly marked, often in the living rock. As might be expected, in accordance with the theory of isostasy of the earth's crust, these lines are now raised towards the former center of the ice sheet, from which the maximum ice load was taken away. Nearest this point the epiglacial sea beach and terraces now reach 200 meters above the sea, with a gradual fall towards the outer coast, where their height is only some 20 meters or less. The gradient in the fall is much greater than in Lake Agassiz, reaching 1.2 meters (4′) per kilometer, against 0.10 meters (20″), but it is clearly the same cause that has been at work in both cases.

The height of the deuteroglacial ice sheets seems to have been almost the same as in the proteroglacial—less than 2,000 meters maximum above the present sea level.

The epiglacial terraces contain in some places banks of shells with quite an arctic aspect. The deeper clay has *Leda artica* as its leading fossil. The climate must have been very like that at present in South Greenland, and the topographical physiognomy must also have been very much the same, with a partially alpine foreland (which constituted nunatak forms as in the proteroglaciated epoch), and with glaciers at the heads of the fjords, with great clay bars or deltas before them, and with small floating icebergs to score out the strandlinjer—the sea beaches in the rock.

It is altogether probable that a meteorological map of Nor-

way in epiglacial time was very like a modern map of Greenland. The isotherm of 0°C. for the year must have followed the southern coast perhaps as far up as to the polar circle. The lower isotherms must have enclosed a pronounced minimum to the east of the ice shed, where certainly — 20°C. must have reigned.[1] While the difference from the present mean temperature at the coast was only 5 to 6° C., the difference near the pole of maximum cold must have been 15° C. at least. This great difference, which is a necessary consequence of the contrast between coast climate and the pronounced continental climate over the east side of the great ice field, is as yet not sufficiently noted by the students of glacial time. An exact consideration of the distribution of the meteorological elements above the inland ices will give the solution of many glacial problems. I shall here only remark that the snowfall in this continental region must have been almost imperceptible as in winter in Siberia now—and likewise the melting. Now, the power which keeps the glacier in motion is ever the surplus of snowfall. The whole continental side of the inland ice must thus be kept in quite a passive motion, be pushed as a rather thin ice plate out to the margin by the press from the greater snowfall on inside ice nearer the ice shed and the coast. The reliable measures of the ice sheet in the Baltic show really very small dimensions—less than 200 meters—thus it will become intelligible why the greater ice masses to the west can keep the ice divide four to six times nearer the western margin. An ice plate of about 100 meters or less must be impotent to erode. The bottom moraine from the more powerful inner part must be gradually built up *below* the outer thin marginal ice sheet. On the continental side we will have formed a regular boulder-clay or thick bottom moraine outside an area where denudation in the form of broad shallow basins or plains will still take place—all this against the deep rock basins with terminal moraines and terraces before them, on the coast side. The snowfall here will be very great. The surplus ice

[1] Cf. H. MOHN's meteorological map of Greenland in Wissenschaftliche Ergebnisse, von Dr. NANSEN's, Durchquerung von Groenland, Gotha, 1892.

will be carried with considerable speed by steep glaciers to the sea; the localized erosion will be very energetic; and we will get the fiords and the lakes—while the eroded matter will only be deposited *before* the glaciers as terminal moraines and terraces.

As the ice shed will be rather near the coastward margin of the inland ice, it follows that it is for a great part the enormous snowfall on the great western glacier's own surface which is to be transported. Hence these glaciers can follow more irregular lines from the first, only deepening and widening the preëxisting valleys, and so we get the complicated fjord systems; while, on the continental side, where a more uniform *vis a tergo* pushes the ice plate forward, the eroded depressions must be more regular. It is quite necessary to keep in view this great contrast between erosion and deposition on the part of the continental and the coast sides of the great ice sheets, respectively, in order to be able to understand many of the complicated glacial phenomena.

We have seen that the deuteroglacial and especially the epiglacial inland ice had its ice shed far to the east from the watershed. Across this divide the ice must move and with somewhat accelerated speed in the narrow defiles. There must here originate passes or gaps (skar in Norwegian) across the watershed. Of these, we really have very many in Norway with a development in distinct relation to the distance between the ice-shed and the watershed and to the greatness of the epiglacial lakes and valleys on both sides. In not a few we have lakes with outlets on either side.

When the ice stream through such a gap came out to the western edge of the high plateau, there resulted a sort of ice cascade, which, like a waterfall, receded with rather great speed. These receding icefalls evidently gave origin to most of our *fjord-valleys*, *sack-valleys*, *culs de sac* interior to the fjord heads. Also these must generally be of deuteroglacial origin, as only then the ice flowed in great streams across the watershed.

The epiglacial stage of the deuteroglacial period must have had a very abrupt termination. The glaciers retired from the

epiglacial lakes without filling them up in any considerable degree. The ice melted so speedily away, and the crust swelled up so fast, that the deposits of the rivers just below the epiglacial terrace level are very small. This could only occur with a climate more genial than the present in which an existing glacier as great as the epiglacial land ice would certainly assert itself with success.

We must suppose a considerable uplift of the snow line in this time which followed the epiglacial period, and which I shall call the *Boreal period*. Such a genial climate in early post-glacial time we are forced to assume also on biological reasons. On the warm valley sides in the western interior fjords, we find many plants which can only prosper in a temperature more than 2° C. higher than now prevails in the intervening tract across which they must necessarily have immigrated. On the southwestern coast flourished a vegetation almost like the Irish coast flora, but separated from its main habitat by a temperature perhaps 4° C. lower in January than it will bear. These Boreal and Atlantic plants can only have spread to their isolated places in Norway in a climate some 3° C. warmer than the present. That this warmer time did occur in early post-glacial time is again proved by the stratification in the peats, where the plants most susceptible of cold (ash, oak, etc.) are found in the deepest layer or rather on the bottom itself—this also in places on the coast and in the mountains where now no forest tree grows.

These 3–4° C. recorded by the vegetation would certainly have raised the snow line, which now is 1200 to 1800 meters above the sea in Norway, above almost the whole epiglacial ice sheet, which nowhere attained 2000 meters. The great inland ice must then have become a *dead* glacier, and must have melted rapidly, especially from the margins. The last remnants of it might be supposed to have been situated near its maximum elevation, *i. e.*, near the ice shed. This lay, as explained above, in deuteroglacial time at some distance to the southeast of the land watershed, as the many boulders in the upper eastern valleys which were transported upwards prove. The ice remnant is then to be

sought for as far as 100 kilometers to the east and south of the watershed. This southern position was moreover accentuated by meteorological facts. The western moist winds are intercepted by the broad western alpine foreland and the high land near the watershed, while the low country at the southeast would give the moist winds free access to the southern glacier side. The country close to the watershed on the southeast now gets almost all its humidity from the southeast winds, but these would, in early post-glacial time, be barred by the inland ice, which in this way would come to have a very dry north side, in contrast to a very moist south side. This would draw the last inland ice out to the south-east edge of the mountain plateau to a point not far above the great epiglacial lakes in southern Norway.

But the melting of the inland ice did not go on uninterruptedly. When the land had risen more than half the post-glacial uplift, and when, presumably, the ice was more than half gone, a new deterioration of the climate commenced. It is possible it did not get worse than the present, but it was enough to stop the melting of the inland ice, which again arose above the snow line. The ice again assumed the character of a living glacier, and kept its position unaltered for a long time. Under the pressure of this constant ice load the land again was kept at a constant level. We find, especially in northern Norway, a new strandlinje (sea beach), occurring at about 40 per cent. of the epiglacial and great terraces, built up with a fauna quite like the modern. This new marked phase in postglacial time I have called *the subglacial period*, denoting its half glacial condition. In Sweden this epoch is also marked by a very distinct beach line, but in Scania and Gothland this low raised beach in places is built upon peat, which shows that the uplift of land in the Boreal period did exceed that in the following. For this reason, the Swedish geologists speak of the *post-glacial depression*. The term post-glacial for this general phase is very unfortunate. It must necessarily literally denote all the time after the deuteroglacial-epiglacial period, for which time we have no other name. And as the constant level in Norway only represents a single phase in the

general post-glacial upheaval, and as the depression in southern Sweden may be a quite local, peripheric phenomenon attached to the Baltic, I must insist upon the more significant, yet neutral, form *subglacial* period for the age of the lower beach line.

The inland ice was then, as explained, reduced to a zone (about 50 kilometers broad) across the middle of the eastern valleys. This fact must have a curious consequence in the fact that these valleys must have been dammed up by the ice and filled with lakes whose outlets ran west and north through the gaps in the watershed. These glacial lakes have actually left very distinct marks in the greatest eastern valleys in Norway, Gudbrandsdal and Oesterdal. We not only find in their upper tracts enormous terraces of material brought by the glacier from the south, terraces without any parallel on the other side of the watershed, but we also find here very fine beach lines—*seter*—partially cut in the rock, corresponding in height with the terraces and with the draining gaps, 620^{m}, 660^{m} respectively—quite like the famous Parallel roads of Lochaber, but very much more extensive. From these ice-dammed subglacial lakes there flowed great rivers across the present watershed filling up with their heavy sediment many of the epiglacial lakes on the northwestern coast, and building great subglacial clay terraces at the level of the lower ancient sea beach.

The erosion of the marginal glaciers has set its mark also in the subglacial time in some inland lakes as Storsjö and Sensjö, in Oesterdalen, Mösvatn and Totak, in Telemarken which have their greatest depth in the upper part and terminal moraines at the present upper end of the lakes.

So far as I can see the subglacial period also prevailed in North America, without receiving yet, however, due attention from glacial students. I cannot here deal with all the raised beaches in the east formed by the sea and by the lakes which naturally can be referred to this period, but I shall use the occasion to point out that the apparently insoluble difficulty in harmonizing archeological and biological facts with the geological data connected with the ancient "Quaternary" lakes in the Great Basin

will immediately vanish when the two great humid periods are regarded not as proteroglacial and as deuteroglacial, but as deuteroglacial and subglacial or—what I think is more probable—as correlate with the two Norwegian post-glacial warm periods (before and after the subglacial), the climatic changes caused by a shifting of the pole westwards, which alone is able to account for the late glaciation of the Cordilleras in Atlantic post-glacial.

At last also the subglacial remainder of the inland ice commenced to melt away in the warm subboreal period. The country rose farther above the sea, and finally, by some intermediate steps, attained its present position. The modern sea beach shows everywhere so great a development, and is so sharply built, that all alleged displacement in historical times must be received with the greatest distrust. We have, notwithstanding all such relations, full reason to maintain that the seashore since the ice left has remained practically unchanged, as also the climate in historical time. We have reached the constant *recent period* in the most rigorous sense, and therewith conclude our synopsis of the Quaternary history of Norway.

There is, however, yet a problem of capital interest, which I cannot quite pass even in this short account. It is the question, When did *man* appear in geological history? The evidence given in Norway is, however, not very direct. We have seen that all traces of preglacial life were swept away, except the littoral find at great depth at Storeggen. We have also seen that the traces of interglacial life are very doubtful, and that we were obliged to go to Denmark to get better information about interglacial time. We have found that the Arctic flora here (with the reindeer) which flourished upon the proteroglacial bottom moraine, was superseded by the aspen vegetation (with elk) when the reindeer had already disappeared (J. Steenstrup). Now we know that in central Europe paleolithic man was contemporaneous with the reindeer, which will date this reindeer period back to the close of the proteroglacial time, and probably yet higher up. But in Denmark, it is only with the next vegetation, with *Pinus sylvestris*, that the first traces of man

appear, represented by the well-known refuse heaps, the *kökken möddinger*, where, with shells and bones of *Bos primigenius* and *Alca impennis*, are found many rude instruments of horn, bone, or stone. This culture, which did not know any other domesticated animal than the dog, is by some archeologists called mesolithic. *Kökken möddinger* and implements of the same type, *the coast finds*, are only discovered in non-deuteroglaciated places of Denmark and Sweden, which fact alone goes far to prove the assumption that the *Pinus sylvestris* period really is interglacial, as I have advocated above. And the molluscs in the refuse heaps on the northern shores of the Danish isles are quite the same as in the (upper) *Cyprina*-clay on the southern shores, which overlies the proteroglacial moraine, and is here generally ploughed out by the rather feeble margin of the deuteroglacial Baltic ice tongue. This interglacial layer contains often a stratum with fresh water molluscs and in this supramarine deposit there was found in Langeland shells of *Cardium edule* and *Nassa reticulata*, in which I cannot but see a rudimentary *kökken mödding* and a proof for the interglacial age of this mesolithic culture.

From Norway we have only a few finds of implements of this type, as might be expected, because the habitable coast was so greatly depressed and covered in the following deuteroglacial period. But it is reasonable to suppose that it also was inhabited by a population akin to the Danish. When the latest ice sheet pushed forward to the great mostly-submarine terminal moraine, the retreat of this population on the western foreland was intercepted, and interglacial man was obliged to adjust his mode of life somehow to Esquimau fashion. But there is no reason to think him quite exterminated here on the shore of the life-giving Atlantic. And anthropologic studies have indeed proved that on the western margin, just so far east as the deuteroglacial ice left land outside, there lives yet a brachycephalic population, while everywhere else (even in the innermost western fjords) dolichocephals and mesocephals are in great majority. This distribution of anthropological types is quite unaccountable by any other supposition than that the brachycephals are descend-

ants of the interglacial Norwegians and that the whole deutero-glaciated country was peopled by Aryan dolichocephals in early post-glacial, boreal time. We know that these new immigrants had at least four domesticated animals, and were in possession of the art of grinding their stone implements. Can we now date the appearance of *neolithic man* by more direct geological means? There are found so many flint implements in such depth in probable subglacial terraces in Norway that it may be taken for granted that the country was populated, however sparsely, up to and beyond the polar circle in subglacial time. In Sweden polished implements have been discovered in the peat layers below the subglacial beach, so it will perhaps be reasonable to refer the first appearance of neolithic man also on geological dates to the genial Boreal period between epiglacial and subglacial time. Approaching our own culture, we find that the country in the *bronze age* was still depressed. In Smålenene, to the east of Kristianiafjord, are observed about 150 rock sculptures from the bronze age which are situated at about 22 to 25 meters above the sea; none at lower levels. As these sculptures almost always are made along a shore, we are justified in supposing that more than ten per cent. of the land yet was unfinished in early bronze age. From early *iron age* we have barrows quite near the present constant sea level, so we may assume that the recent geological period coincides with the iron age and historical time.

If the theory of ice depression is correct, there must, even in the bronze age, have existed a remnant of the inland ice, which, as explained before, must be sought for across the middle of eastern valleys. In this zone we could not expect to find implements from the stone age or bronze age. There has as yet been found only four stone hatchets in all the districts near the former ice shed, against many hundred stone implements in the districts on both sides of the same valleys, and these perforated hatchets have been in use far down in metallic time.

The ice zone must have stopped the immigration as the inland ice of Greenland does now. This is the reason together with the

depression of the coast land why neolithic man did not go farther up in Sweden than 61° northeast, while the Norwegian coast was free all along, and permitted his advance up to 70°. Another consequence is that the northern part of the long valleys in southeastern Norway must get its first population from the west coast. This is also proved to be the case, not only by the existence of a well-marked anthropological boundary across these continuous valleys, but also by a singular contrast in dialects and traditions. Reversedly, this signifies that the present Scandinavian race really was the first post-glacial occupant of the country. In the administrative divisions we find traces of the old ice barrier as far down as only a century ago. It is thus possible to follow the effect of the ancient land ice in Norway down to our own day.

In closing this hasty summary of the Quaternary history of Norway I cannot quite omit the doubtful question about the absolute chronology. We have seen that in the bronze age which the archeologists are able to date in Scandinavia from 1700 to 500 B.C., more than ten per cent. of the post-glacial upheaval was not yet accomplished. As the upheaval has not been uninterrupted, we cannot directly conclude that the whole elevation has had a duration of about 30,000 years. The long time from early iron age in which the shore line has been constant enters into our standard. But we can draw a more reliable comparison between the terraces from the different periods, when we take the greater eroding power of the old inland ice and its greater glaciers in due consideration. I cannot here specify my calculations, but will say that I regard myself as on the safe side when I compute the time for forming the subglacial terraces and beaches to not more than double the last constant period, which may be reckoned at 2,000 years. For these two constant post-glacial periods together we thus get about 5,000 to 6,000 years. The relatively small terrace deposits from the remainder of post-glacial time cannot by any means give more than half this value. We may, therefore, on this, as I think, very reliable estimate, calculate the whole post-glacial time to be 7,000 to 9,000 years. To about the same numbers

I have come by calculating from the mean depth of neolithic finds in Norwegian peats, but this computation has not quite so much importance, though the fact that the generally adopted archeological chronology agrees as well with geological estimates certainly has some weight.

I shall recall the fact that calculations on the length of post-glacial time based on the receding Niagara, St. Anthony Falls, or the Michigan lake shore, on boulder pedestals in Scotland, the denudation of the Somme, the Plum creek, or the Raccoon valley, deposition of the Tinière or the Rhone, etc., delta, the thickness of glacial clay in New Hampshire and in Sweden, the rate of growth of peat in North America and Ireland, the atmospheric waste of the Parallel roads in Lochaber, the depth of some ancient neolithic finds, that all these give numbers of about the same value, 5,000 to 12,000 years. Doubtful as some of these chronometers may be, all fair chances are against any supposition which differs in any considerable degree from those of about *thirty independent* estimates I have got together. With full regard to a legitimate calculation of probabilities, it may be predicated that the number of 7,000 to 10,000 years is as nearly an exact estimate of the *duration of post-glacial time* as can ever be expected.

It is now tempting to try a comparison between the subglacial and the epiglacial terraces and lakes in Norway. When the much greater eroding force of the epiglacial glaciers is properly reduced, I do not think it can be very much at variance with the truth to compute the epiglacial period to be between five and ten times the duration of the subglacial, the smaller number being somewhat more probable. We would then get *10,000 to 20,000 years for the epiglacial period and perhaps 15,000 to 25,000 for the whole deuteroglacial time*. For the *interglacial period*, the Norwegian geology cannot as yet give any reliable measure but the depth of the aspen and pine layers in the Danish peats as compared with the post-glacial oak and birch layers does answer very well to the American estimates of one and one-half to two times the duration of post-glacial time—let us take about 15,000 years. We may next compare the proteroglacial fjords with the epiglacial lakes

and may by these means get some idea as to the length of the first great ice age. The farther we go from our own time the more wholly conjectural will our numbers become, of course. But as other more reliable measures as yet are wanting, I shall venture a first approximation, calculating the time in which the enormous proteroglacial marginal glaciers eroded our fjords, as five to ten times the epiglacial time in which our great epiglacial lakes were scooped out—the higher estimate in this case being somewhat more probable. This would perhaps make *100,000 to 150,000 years for the whole proteroglacial period, i. e.*, about five times the duration of the deuteroglacial time—a relation which, as far as I see, is in very good accordance with the general quantitative difference between the effects of the first and second great glaciations. This will give for the whole Quaternary-post-tertiary time about 140,000–200,000 years.

I see very well how precarious such computations may seem, especially as I here cannot give the detailed calculations—but I do not think it possible that any of these have given numbers five times too great or small. Under these circumstances they must be taken for a very good geological approximation. By getting parallel estimates from other glaciated countries, it will appear, I think, that we will have, on wholly geological ground, more positive and reliable data for the Quaternary chronology, than those derived from astronomical speculations.

I add for greater ease in comparison my reading of the Quaternary history of Norway in a tabular form.

ANDR. M. HANSEN.

SYNOPSIS OF QUATERNARY HISTORY OF NORWAY.

Period.	Epoch.	Ice Sheet.	Elevation of Land.	Erosion.	Deposits.	Temperature.	Fauna and Flora.	Man.	Probable Duration (1000 yrs).	
Protero-glacial.	1. 2.	1. Grows to the ocean slope. 2. Terminal glaciers in the fiords, eastern margin near Petschora.	Sinks from 2-400 M. above the present to about the present (?)	1 & 2. Norwegian channel. 2. The great fiords.	Undermost bottom moraine on continental side. Terrace plain sub-marine around the west coast.	Sinking from the warmer Pleistocene to 8-10° C. below the present mean.	Arctic.	No traces.	100–150	
Interglacial.	1. 2. 3.	None (?)	The present (?)	The present forces.	Intermediate sand layers at Jaederen (?)	At times warmer than now.	1. { Reindeer / Dryas 2. { Elk. Populus / trem. 3. { Bos primig. / Pinus sylv.	3. Danish kökken möddinger. Western brachyceph. in Norway.	15–20	
Deutero-glacial.	1. Ra-Epoch. 2. Epi-glacial.	1. Grows to the fiord heads, terminal moraine Baltic tongue. 2. Terminal glaciers in the lakes behind the fiord heads.	1. Sinking to about 250 M. below the present near the ice centre. 2. Upper ancient beach.	1 Ra-lakes and intermediate lakes behind moraines. 2. Great lakes near the fiords. Gaps at the watershed. Sack valleys.	1. Terminal moraine. Upper diluvium round the Baltic. 2. High marine terraces.	2.5-5° C. lower than the present.	2. Arctic (Leda clay).	?	2. 10-20.	15-25.
Postglacial.	1. Boreal. 2. Sub-glacial. 3. Sub-boreal. 4. Recent.	1. Melting rapidly. 2. Gone except across the eastern valleys. 3. Melting away. 4. Gone.	1. Rising rapidly. 2. At the lower (40 pct.) ancient beach. 3. Rising to the present. 4. The present.	1. Rivercuts in epiglacial terraces. 2. Lakes in central Norway. Seter. 3. As now. 4. The present.	1. Small terraces. 2. Terraces at 40 pct.; inland terraces. 3. Small terraces. 4. The present.	1. About 3° C. warmer. 2. As now. 3. Somewhat higher. 4. The present.	1. Boreal (oak, ash). 2. As now. 3. Some southern forms. Pine in the peats. 4. The present.	1. Neolithic immigration. 2. Neolithic man. 3. Bronze age at 10 pct. of the upheaval. 4. Iron age, historical time.	2. 2-3 4. 2.	7-9.

NAES. HEDEM. AUGUST, 1893. ANDR M. HANSEN.

DUAL NOMENCLATURE IN GEOLOGICAL CLASSIFICATION.[1]

At the meeting of the American Association for the Advancement of Science, at Rochester, in 1892, while discussing a paper of Professor James Hall, read by Mr. Merrill, on the classification of the Devonian rocks in eastern New York, I ventured to express the opinion that the time was ripe for the recognition of the duality of the group of facts which geologists attempt to classify in what we call the geological column or scale of formations.

Since that meeting, Mr. Darton has published a paper[2] restating and commenting upon substantially the same facts reported by Hall and proposing a special use of the name Catskill. Still later papers have appeared by Professors Stephenson[3] and Prosser[4] discussing the proposition made by Mr. Darton, the one from the stratigraphical, the other from the paleontological point of view. There is also now going on the preparation of a revised geological map of New York state, containing the typical paleozoic section for North America. These and other reasons have led me to think it not inopportune to ask the serious attention of geologists to the adoption of a dual method of nomenclature in the classification of the facts of historical geology.

There is nothing novel in the proposition that there are both stratigraphical and chronological divisions in the geological classification, but it is only recently that practical geologists

[1] Presented to the Geological Society at its meeting in Boston, December, 1893.

[2] Oneonta and Chemung formation in Eastern Central New York. Am. Jour. Sci., III., Vol. XLV., p. 203.

[3] J. J. Stevenson: On the Use of the Name Catskill, Am. Jour. Sci. III., XLVI., 330.

[4] C. S. Prosser: The Upper Hamilton and Portage Stages of Central and Eastern New York, Am. Jour. Sci., III., XLVI., p. 212.

have seen the importance of classifying *terranes* and *periods* separately.

James D. Dana,[1] in 1855, set forth, with great clearness, the importance of the chronological classification of rocks, and in his manual[2] all geologists have been made familiar with the meaning of a chronological classification of stratified rocks, but the classification is a classification of rock strata, and the time-divisions are those determined by the strata, so that but one nomenclature has been needed or used.

The International Congress of Geologists was the first to distinctly formulate a dual method of classification, but here, too, it was only two ways of classifying one set of facts that was proposed. The divisions of the scale have been identical and in the terms of strata. The Congress was organized for the purpose of unifying nomenclature, but one of the most important results of the Congress has been the discovery that uniformity, in the sense first proposed, is not practicable.

In advocating a dual nomenclature, I would carry the differentiation one step farther, and propose that we give a different nomenclature to the time-scale, and classify it independently from the terrane-scale, because the fossils by which its divisions are determined contain, in themselves, the evidence of their time relations. In an article in THE JOURNAL OF GEOLOGY[3] I described the history of the elaboration of the system of nomenclature and classification now in use, and showed how the geological formation is the actual unit of classification in the present system. Having called attention to the fact that the geological formation and the geological period have become thoroughly differentiated, I remarked in closing that "the elaborating further and making more precise the geological time-scale must come from a direct study of the life history of organisms as

[1] See Proceedings of the American Association for the Advancement of Science for 1855; also On American Geological History, Am. Jour. Sci., II., Vol. XXII., pp. 335-344.

[2] DANA: Manual of Geology, 1st edition 1863, 2d edition 1874, 3d edition 1879.

[3] The Making of the Geological Time-Scale. JOUR. OF GEOL., Vol. I., pp. 180-196. See also Elements of the Geological Time-Scale, Vol. I., pp. 283-295, 1893.

recorded in the stratigraphical formations" (p. 197). It is the carrying out of this thought which requires the adoption of a dual nomenclature in the classification.

Perhaps the best thing that can be said in favor of such a proposition is, that it will enable us to record the facts of our science with greater precision, accuracy, and truthfulness; and nothing worse, I think, can be said against it than that it will cause confusion and difficulty in mapping and in the estimating of the relations and values of the old terms and system of classification, this simply because it is not the old system. Evolution has worked the same difficulty in the classifying of organisms, because it has suggested that species are changing and not fixed quantities, and in the early part of this century the principle of identification of rocks by their fossils upset, in a similar way, the elaborate classification of the Wernerian school based upon the supposed natural sequence of particular kinds of rocks.

Where new geology is being elaborated, the application of the dual method may be easily attained, and the adoption of the method by the United States Geological Survey has therefore been found possible and practicable. But the greatest difficulty, and hence the real retardation of progress, is found in applying the method where standards have been established and used on the old basis. The New York rocks constitute, for North America, the standard section of Paleozoic geology. They were classified on the basis of unity and integrity of geological formations.

By unity, I refer to the notion that a geological formation is an integral unit in the single geological stratigraphical column, which may be identified in distinct geographical regions by its fossils; and by integrity, I mean the notion that a formation is the same in its position in this column, wherever found, thickening and thinning, and even changing somewhat in the character of its material from place to place, but always the same in its relation to other formations.

Therefore, in discussing geology in North America, it has become a practice to use such terms as Oriskany, or Niagara, or

Potsdam as names of geological divisions of the scale of which there are a definite number. These arranged in a definite order, according to English sequence of systems: Cambrian, Silurian, Devonian, and Carboniferous, etc., constitute *the* standard geological scale.

These formations have also been called Epochs and Periods, and because the succession of time is continuous, the strict application of the method has required the filling of the whole interval, from the Cambrian to the Carboniferous, by these formations, except when unconformity gives marked evidence of break in the record. The old system requires that in all the sections, the lines separating the formations from one another shall coincide with the stratigraphical divisions, and progress has been checked by the authoritative rebuke, from those who are supposed to know, of any timid suggestion that the geology of a newly discovered section does not conform to the standard. We are already familiar with the proposition that there are such systems, groups and formations, on the one hand, and Ages, Periods and Epochs, on the other, but our whole nomenclature and classification is applied and used as if the divisions indicated by the two categories were strictly synonymous; in fact, the nomenclature of the International Congress went no farther than to propose that the names of the divisions of the one category, viz.: *group*, *system*, *series*, *stage*, should be applied to the same concrete geological facts as the corresponding names of the other category, *era*, *period*, *epoch*, *age*, and that these names of the categories should be universally used; as if, a century ago, zoölogists had proposed that class, order, family, genus, be used in a uniform manner by all naturalists. It is the essential idea contained in this differentiation of nomenclature, in two directions, which I would here emphasize and elaborate.

When geologists consider the two scales, the time-scale and the formation-scale, it is found that the divisions are not synonymous, but that there are two distinct sets of facts confused in our present nomenclature and classification. There is a geological time-scale, and, however we subdivide it, or however we

mark or distinguish the divisions one from another, as a scale it is one and continuous, the parts or divisions of the scale come up to each other and are in a regular succession, but they cannot, from the nature of the scale itself, overlap or duplicate each other. Uniformity in nomenclature, and definite well-known standards and limits, and accepted means of recognizing each division for universal use, are essential to the perfection of this time-scale. In all geological literature only one name should be applied to each subdivision of the time scale, and there should be recognized for each of the grander divisions a prime standard, in some particular place on the earth, whose marks may be examined with closer and more minute discrimination as the science develops in precision. Further, in each continent we need separate standards which shall be compared as accurately as possible with the prime standard, so that each continent may have its typical geological time-scale, in concrete form, with which local formations may be corrected.

The above applies, however, only to the time-scale; the list of geological formations is a totally different thing; there is no universal uniformity of geological formations; to attempt to apply a single set of names to them is always more or less to cramp and distort the facts. Geological formations are local affairs, and to restrict geological classification to a single formation scale is to hide-bind the progress of science. There may be as many formation scales as there are examined sections of stratified rocks, and we know that all the marks by which a formation may be defined constantly vary, so that the definition of a formation, small or great, is not alike for any ten miles of its extent, and often ten feet of extension will show clear marks of difference.

Thus we see that there are two distinct sets of facts with which the geologist has to deal, and the United States Geological Survey has clearly recognized this truth in giving rules for the definition and naming of geological formations, independent of time relations, which are left for the more deliberate determination of the paleontologists. It is not, however, in the new work so much as in the revision of old standards that the appli-

cation of the dual system of nomenclature needs to be insisted upon. And when the occasion for revision of an accepted standard, such as the geology of New York state, appears, it is more important to adapt the classification to the needs of the coming century than to preserve the imperfections of the one now closing. It was a bold step when, over fifty years ago, the New York state geologists, Emmons, Mather, Vanuxem and Hall, discarded the then standard Wernerian classification to which McClure and Eaton had, with great pains, adjusted our American geology, and, describing the New York rocks just as they found them, with new names and a new classification, formed the New York system. This New York system has become the standard formation-scale for American geology.

But since the New York system was described, the fossils, which were then looked upon as mere marks by which to identify the formations, have come to be known as the evidences of the gradual evolution of species, each one holding its definite place in a continuous history of organism. As stratigraphy replaced the Wernerian lithology in classifying formations in 1840, so now paleontology comes forward to take the place of stratigraphy as the true means of classifying geological periods.

The case of the Catskill formation is in point. It has been a recognized fact, since the New York State Survey Reports were published, that the Catskill formation of New York was peculiar to the eastern parts of the state, and that it thins out on passing westward, and that the Chemung formation is well developed in western New York, and becomes insignificant or is wanting in the east. According to the single method of geological classification, it is necessary to call one above or below the other, and in our geological columns we have been accustomed to see the Catskill as the upper member of the Devonian lying above the Chemung, and because usage has vacillated between the time-scale and the formation-scale the confusion has been very difficult to formulate, or to bring to the minds of geologists.

If we are discussing the formation-scale, it is true to the facts to speak of the Catskill formation as lying above the Che-

mung formation, except that it does not express all the truth or the exact truth, for when the Catskill deposits are found in relation to the Chemung deposits in a continuous section, some Catskill facies of sedimentation do succeed the marine Chemung, but it may not all succeed all the Chemung, as the testimony of numerous observers in Pennsylvania and further south shows.

When, however, we are talking of the time-scale the confusion is more apparent; for it is clear that one period cannot both precede and follow a second period. Either the Catskill Period must follow the Chemung, or the Chemung must follow the Catskill, or else they are synonymous terms, and one is superfluous. When Mr. Darton proposes that Catskill be used in place of Chemung, he is reasonable on the old basis of the old method of classification, but the facts are not thus elucidated. The facts are that the Chemung period is synchronous with a part of the Catskill period, but that the Catskill formation is distinct from the Chemung formation, and when they occupy the same section the Catskill formation succeeds the Chemung.

Those who have watched the discussion of the classification of the Upper Devonian, will remember that one of the greatest difficulties presented in the progress of field studies has been the fact that collectors have so frequently reported fossils where they ought not to be. Formations, classified as Catskill in the books, have yielded Chemung fossils, or, above so-called Catskill rocks, Chemung fossils have appeared, or above Hamilton rocks, in rocks regarded as Portage, have been found Hamilton fossils again. Geologists on the Pennsylvania Survey have met with serious rebuke for proposing Chemung-Catskill and similar names which have thrown discredit upon the integrity of the formations. These discrepancies have been interpreted to be evidence that the observers could not tell the two formations apart, or had been mistaken in their observations; but the true interpretation is that the criteria for determining the divisions of the time-scale have disagreed with the criteria of the formation-scale. The latest phase of the discussion has appeared in the papers of Stevenson, Darton and Prosser, before cited.

In the discussion of Professor Hall's paper at the Rochester meeting, the question came definitely before us as to the relative value of fossils and structure as means of determining or tracing equivalency of age of formations. In that discussion I maintained that fossils are always the only certain means of carrying from one geological basin to another the evidence of time-relations of the deposits, that structure was indicative of equivalency only when actual continuity of a formation can be traced. Both of Mr. Stevenson's [1] papers recognize the physical features of the formation to be of great importance in determining its position in the time-scale, and in his use of terms he appears to be classifying formations and yet using the language of the time-scale. In his presidential address he maintained, as quoted by himself, that the series of beds included within the Catskill and Chemung Periods should be grouped into one period, the Chemung, with three epochs, the Portage, the Chemung and the Catskill (page 320), and in his paper in 1893, he insists that the Chemung, and not the Catskill, is the epoch whose name should be applied to designate the whole group, while Catskill must be retained in its original signification only.

Mr. Darton, on the other hand, is discussing the formation-scale alone. The principal purpose of his investigation is said to be to determine the relations and distribution of the Oneonta and Chemung formations (p. 203). In the passage on the status of the name "Catskill" the author proposes to discontinue the use of Catskill as a coördinate formation term, and use the term "Catskill group," to include the Portage and Chemung formations (p. 209). He maintains, correctly, I think, that the term Catskill has been applied in the past to beds of a certain lithologic character—the hard sandstones and red shales—and it has had no definite stratigraphic significance. The rocks of the Catskill Mountains and westward have no distinctive fauna of stratigraphic significance, and they cannot be correlated on paleontologic grounds (p. 208).

[1] "The Chemung and Catskill (Upper Devonian on the Eastern Side of the Appalachian basin)." A. A. A. S., Vol. 42.

On the use of the name Catskill. Am. Jour. Sci., Vol. XLVI., p. 330.

On the assumption, which has been the common practice up to the present time, that the divisions of the time-scale and of the list of formations are synonymous, it is reasonable to insist that the Catskill and the Chemung are not correlative terms, and that, in case we apply them as formation names, the one must succeed the other, but I think we all know that this is not the case. We know, that is, that in western New York a continuous section takes us through Hamilton, Portage, Chemung, Conglomerate and Carboniferous formations ;[1] that a like section in the meridian of Cayuga Lake takes us through Hamilton, an interval filled with *Spirifer levis* beds, the Ithaca group and 600 feet with Portage fauna, then the Chemung, the Catskill, and finally the Carboniferous. Farther east the interval between the Hamilton and Chemung is filled by rocks with an advanced stage of the Hamilton fauna; then the Oneonta and next rocks with another stage of the Hamilton fauna, then the Chemung and the Catskill. Still farther east, Chemung drops out from the series; and if we go on to Maine and Eastern New Brunswick, the Hamilton also falls out, and a long series with the latest marine fauna an Eodevonian Oriskany fauna, separated from the Carboniferous deposits by several thousand feet of deposits which, faunally and structurally, may be considered equivalent to the Catskill of New York. It is evident, thus, that at different localities the Catskill formation has a time value in one place equivalent to the closing part of the Chemung formation; at another place to the whole of the Chemung; at another to the upper part of the Chemung, and also an earlier stage during the formations of the Ithaca formation; at another place it represents the whole upper Devonian, and, if we mean to extend the use of the name to Maine, to the whole of the upper, middle, and most of the lower Devonian.

It is, therefore, clearly inappropriate to use the term Catskill as a name in the time-scale, because it has no common definition in that scale. It is an appropriate local formation name for deposits succeeding Hamilton or Chemung formations in Eastern

[1] See the table on p. 155.

New York and farther southwest. It should not be applied to cover the three divisions of the Upper Devonian, because as a time indicator it is inappropriate, as just stated; and as a formation name it has already a use, and should not be used in two senses; and, thirdly, even if used in the more comprehensive sense, it is inapplicable because the Portage and Chemung are not represented, at least only imperfectly, in the geological area named Catskill.

The Catskill is a distinct and well defined geological formation, but it is not a period or an epoch, nor does it represent any particular period of geological time. The classification of the Upper Devonian deposits is a very difficult matter when it is attempted to make a continuous series of the formations of New York alone. As I have previously shown, the succession of faunas in the sections of New York rocks at distances of not over fifty miles apart make plain this fact. At the Cayuga lake meridian, the section is Hamilton, terminating with Tully limestone and Genesee shale, then the Ithaca group, which has first a Portage fauna, then the Ithaca fauna, third, the Portage fauna again, and finally Chemung capped by Catskill and Carboniferous. A little further east of the Chenango valley, it is Hamilton; then a fauna intermediate between Hamilton and Ithaca (but no Tully or Genesee); then the Oneonta, a brackish and fresh water fauna; then the late Ithaca fauna, still with Hamilton types in it; no Portage fauna, but Chemung fauna following the upper Ithaca fauna.[1]

In this faunal succession there is a clear indication of the age of the Oneonta sandstones. It is clearly in the midst of the rocks characterized by the Ithaca fauna. As I have shown in the paper referred to,[2] the marine Brachiopod faunas occupying the place between the Hamilton and the Chemung faunas in Central New York, of which the Ithaca is the best known, are modified successors of the Hamilton, or Mesodevonian fauna, and the Oneonta group, with its fresh and brackish water fauna is in the

[1] WILLIAMS: The Classification of the Upper Devonian. Proc. Am. Assoc. Adv. Sci., Vol. XXXIV., p. 225, 1886.

[2] Proc. A. A. A. S., XXXIV., 1885, pp. 222-3.

midst of it; that is, the Ithaca fauna is both below and above it. Again, upon going further west, the same interval is filled by a non-brachiopod marine fauna, *i. e.*, that of the typical Portage group of Genesee valley, and the Ithaca group of Ithaca is in the midst of the corresponding rocks of the Portage, as the Oneonta is in the midst of the Ithaca. This I interpreted, in the paper referred to, as indicating that the succession of faunas was controlled by oscillation of levels during the accumulation of the deposits, the eastern shores rising during the first half of the Portage (of the Genesee valley series) so that, during the particular stage represented by the fossiliferous zone of the Ithaca group, Portage fossils were being accumulated in the Genesee valley sediments, Ithaca fauna at Cayuga lake meridian, and, from Chenango eastward to Oneonta, sands with fresh water Amnigenia and Holoptychius characteristic of the Catskill formation.

THE FORMATIONS OF THE DEVONIAN SYSTEM IN THE APPALACHIAN REGION AND THEIR RELATIONS TO THE TIME-SCALE.

Time Scale.	Formation Scale.				
	Genesee River.	Cayuga Lake.	Delaware Co.	Hudson River.	Maine.
Eocarboniferous	.....	.....	.....	.....	.....
Neodevonian	Conglomerate Chemung Portage Genesee	Catskill Chemung P² Ithaca P¹ Genesee Tully	Catskill Chemung H Oneonta H²	Catskill H²	Catskill
Mesodevonian	Hamilton Marcellus	Hamilton Marcellus	Hamilton	Hamilton	
Eodevonian	Corniferous Oriskany	Corniferous Onondaga Oriskany	Onondaga Schoharie Caudagalli Oriskany	Schoharie Caudagalli Oriskany	Oriskany
Neosilurian	.....	.....	.....	.....	.....

The table on page 155 presents the facts regarding these formations, and what I conceive to be the chief difficulties in attempting to use a single nomenclature and classification. The question at once arises how will a dual nomenclature help us over these difficulties.

On the left I have placed a part of the time-scale adjusting the formation-scales for the several sections, approximately as I think the fossils indicate their time relations to have been.

Formations may be described for a particular geological section with precision as to kind of rock, stratigraphical sequence and thickness, and, as we compare one section with another, we are obliged to become more indefinite in our description and speak in generalities, or averages ; and therefore the wider we extend the use of a formation name, the less accurate and the more indefinite does it become.

On the contrary, in the distinguishing of time-relations or position in the time-scale, the individual facts, the local handful of fossils are the more indefinite, indicating only, it may be, Paleozoic or Mesozoic age. The extension of the comparison to the study of fossils above and below, and to the comparison of fossils in adjoining sections, and to their geographical distribution for a wide extent, increases the precision in locating position in the geological time scale.

It happens, therefore, that, while formation definitions are best constructed in the field in the presence of the actual rock section, the time definition becomes more accurate the more thorough the investigation of the fossils is made. Hence in constructing a time-scale, it begins properly with the grander divisions, and it is built up and perfected by subdivision, whereas the formation-scales begin with the lesser strata and are elaborated and completed by adding together successive strata.

The grander divisions of the time-scale are already in use. These are universally known as the Paleozoic, the Mesozoic, and the Cenozoic. The primary sub-divisions of these geological *times* are also very widely understood and used. They may be called *eras*, and are named Cambrian, Ordovician, Silurian, Devo-

nian, Carboniferous (constituting the eras of Paleozoic time), Triassic, Jurassic, and Cretaceous (the eras of Mesozoic time), and Eocene, Neocene, and Recent (the eras of Cenozoic time). Each of these eras is known, not by the formations which represent it, but by the fossils which characterize it. Proceeding in the same manner, I would propose that we subdivide the eras into Periods, according to the lines which paleontologists have generally come to recognize as convenient and natural, making a three-fold (or in some cases a two-fold division) of each era, and that they be distinguished by prefixing the syllables *Eo*, *Meso* and *Neo*, to the name of the era, thus : the *Eocambrian*, or the period of the Olenellus fauna, the *Mesocambrian*, or the period of the Paradoxides fauna, the *Neocambrian*, or the period of the Dikellocephalus fauna, and in the Devonian, the *Eodevonian*, *Mesodevonian*, and *Neodevonian*, and in the same manner for each of the other eras.

Although attempts have been made to make finer divisions of the time-scale, into *Epochs* and, lately, into *Hemeræ*,[1] it is doubtful whether our knowledge of the history of organisms is sufficiently advanced to enable paleontologists to define the fauna of an *epoch* so that it can be made use of for more than a thousand miles of geographical extent, and the *hemeræ* of single species cannot be considered as precisely alike in two distinct geological provinces.

In the application of this time-scale to any particular case the degree of minuteness of definition will depend upon the knowledge we have of the time relations of the contained fossils. In the case in hand, the fauna of the Catskill is not sufficiently definitive in itself to enable us to be more precise than to assign it to the Devonian Era. This is affirmed by the fact that, in England, the old Red Sandstone is known not as a part of, but as the representative of the whole Devonian. If we attempt to define the age of the Catskill formation by faunas immediately preceding or succeeding it, the definition in time is equally indistinct, because

[1] S. S. BUCKMAN : The Bajocian of the Sherborne Districts, its Relation to Subjacent and Superjacent Strata. Q. J. G. S., Vol. XLIX., p. 479–522, Nov., 1893.

not alike for different sections which are geographically not greatly separated from each other.

The Catskill formation is primarily a local formation exhibited in the Catskill mountain region of New York, distinguished physically as a series of sandstones and shales with greater or less red-color, and by the absence of marine fossils, and the occasional presence of shells and fish believed to have been of fresh or brackish water habitats. It is the local expression of the broadening shore condition of the continental elevation which brought in the coal-making, or Carboniferous age of eastern North America. As a *formation*, it is separated from what went before by the reddening, or graying of the sandstones and shales, their coarser, more irregular structure, the departure of marine organisms, and the occasional appearance of brackish water shells, fishes, and some fossil drift-wood and plants. In relation to the *time* scale, the period of beginning of this formation varies with the regions in which it is exposed. At its extreme eastern extension, on the peninsula of Gaspe, and in eastern New England, it began in the Eodevonian Period. Along the Hudson River, it began at the beginning of the Neodevonian, or perhaps before the termination of the Mesodevonian. In the region of Oneonta and westward it began soon after the beginning of the Neodevonian Period, and then withdrew eastward, the marine conditions returning over the region leaving the Oneonta formation as its record, and later in the middle of the Neodevonian, it returned and continued on to the close of the Devonian era. In the region of Bradford County, Pennsylvania, it did not begin to be deposited till near the close of the Neodevonian Period. Farther west the Olean Conglomerate marks the final close of the Devonian Era, and the formation in question did not begin till after the close of the Devonian. In the eastern Pennsylvania and more southern sections, its age varies with the locality. In general, it is terminated above by indications of the presence of permanent land conditions, either massive beds of rounded pebbles or conglomerates, or thin beds of coal or carbonaceous shales, or, in the absence of actual change in formation, the line is arbitrarily set by the supposed tracing of

equivalency of stratigraphical position by the structure from some region in which such marks are evident.

The Pocono and the Mauch Chunk are, as formations, but the continuation of the Catskill formation upward and are of local value as formation-names, but of little or no value as elements of a time-scale.

Thus the Catskill may continue to appear in the list of formations of New York, and the Appalachian province, where it generally appears as a Neodevonian formation, but it is useless to define or to discuss its more exact position in the time-scale, because its own time-criteria range through the whole Devonian Era, and its relations to formations whose time-criteria are more exact is indefinite and inconstant.

If we grant the truth of the general principle here set forth, it is evident that the increase of formation names can be no more objectionable than the increase of the names of mountains; and that there is no more reason for applying the same name to two formations which are of the same age, but differ in position and structure, than there is in giving two names to mountain ridges of the same range. The classification of formations into groups or systems will depend upon considerations of geological structure, and only secondarily upon time considerations; and even in the latter case, only because the same general geological events have affected the sedimentation in a similar way for a wide extent geographically.

On the other hand, the time-scale will depend for its classification upon the fossils and not upon structure. Stratigraphical sequence, of course, is important in reading fossils, but only as in a sentence, or on a page, the sequence of the words is important.

An organic species, or a genus, or an order lived only during a particular period of time, and it is for this reason that the fossils have an intrinsic time-value, but a mineral, or a rock may have been formed under like conditions and present like characteristics at any period of geological time. I refer of course to clastic rocks, and those formed through processes of sedimentation.

Marine invertebrates for the Paleozoic, and later marine vertebrates constitute the most satisfactory means for discerning geologic age, because the oceans, in which they live, are of world-wide extent and inter-communication. They are distributed around the globe, and from pole to pole, so far as the adaptation to conditions of environment will permit. Hence, we find it to be a fact that, at every period of geological time, there are representatives in all regions of the globe of the same species, or of closely allied species such as to mark the close correlation of time of their living. While this is true, it must be borne in mind that correlation cannot be made by fossils to a finer degree of discrimination than the facts of specific integrity allow. The life-period of species is not uniform, and the wider the distribution, the longer is, as a rule, the range; so we find, in practice, that with the present knowledge of fossils it is rarely possible to discriminate age to a finer degree than that indicated by the periods, Eocambrian, Mesocambrian, and Neocambrian, or similar periods for the other eras. Within such general limits, time relations can be discriminated by the fossils alone, and the progress of science will enable us to recognize more minute divisions of time as we proceed.

On the other hand, formations, being local phenomena, are discriminated with greater precision locally, and the indefiniteness in application of formation names increases with the wideness of the territory covered. No classification of terranes can be of universal application, for no formation, or formation character, or criterion of determination, is of world-wide extent. The time divisions are more precisely defined the larger they are; the formation divisions are more precisely defined the smaller they are, and progress of knowledge will extend the precision in opposite ways for the two scales.

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ORIGIN AND CLASSIFICATION OF THE GREENSANDS OF NEW JERSEY.[1]

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INTRODUCTION.

DURING the past two years the writer has been carrying on investigations upon the Cretaceous and Tertiary formations of New Jersey under the joint auspices of the State and National Geological Surveys. A preliminary study of the whole area was followed by the mapping, with the aid of others,[2] of three United States Geological Survey atlas sheets in the northern portion of the district, and more recently by the critical examination of five type sections across the state. The results of the earlier investigations have just been published,[3] while the later work will appear in the next annual report of the State Geologist.

In an area which had received such full investigation by as competent a geologist as the late Professor Geo. H. Cook, for

[1] Read before the Geological Society of America, at Boston, December, 1893.

[2] The writer had associated with him as assistants Messrs. C. W. Coman, H. S. Gane and R. M. Bagg.

[3] Rept. of the State Geologist of N. J. for 1892, pp. 167–246.

so many years the head of the State Survey, it was deemed advisable to act with great deliberation before proposing any important changes in the classification. Accordingly the first report to the State Geologist was limited to the fewest possible alterations in the accepted names of the formations, and the work made to conform so far as it was possible with the earlier results of the State Survey. As the work has progressed the necessity of modifying the classification hitherto adopted has become apparent, and such changes are presented at this time. The use of lithologic terms for the formations in the earlier nomenclature will be in the future discarded for place names, the older terms being retained to designate their economic equivalents. Local terms have been adopted, care being taken to select such as would characteristically represent the formations. The names of rivers, hills, and towns, in the vicinity of which typical sections are found, have been generally employed. In this manner the results of the work in New Jersey are brought into conformity with methods generally adopted at the present time in other areas.

The work carried on during the past field season in portions of the area never before studied to any extent on account of the thick covering of recent deposits, reveals the fact that the divisions established chiefly from an examination in the extreme north, are remarkably persistent. This knowledge has been gained to a large extent from recent well openings and borings made at frequent intervals by the writer and his assistants. The unconsolidated character of the sediments render it possible to pursue this method of investigation throughout the region with the hope of far reaching results.

GENERAL STRATIGRAPHICAL FEATURES.

The geological formations of the coastal area of New Jersey represent a nearly complete sequence from the Cretaceous to the Pleistocene. They form a series of thin sheets which are inclined slightly to the southeastward, so that successively later formations are encountered in passing from the northwestern portion

of the district toward the coast. Oscillation in the position of the shore line, and later denudation have occasioned, in many instances, a marked divergence from these normal conditions, so that detached areas are frequently found far removed from the body of the main outcrop.

The formations of the New Jersey coastal area and their economic equivalents are given in the following table :

Age.	Formation.		Economic Equivalent.	
Pleistocene	Columbia Formation			
Neocene	Lafayette	"		
	Chesapeake	"		
Eocene	Shark River	"	Upper Marl Bed	Greensand Series.
Cretaceous	Manasquan	"		
	Rancocas	"	Middle Marl Bed	
	Redbank	"	Red Sand	
	Navesink	"	Lower Marl Bed	
	Matawan	"	Clay Marls	
	Raritan	"	Plastic Clay	

The greensands characterize all the deposits from the Matawan formation to and including the Shark River formation. The glauconite appears in varying amounts and under different conditions in these several formations, so that the lithologic features are often sufficiently distinctive and persistent to be of the greatest service in the determination of the horizons. The presence of greensand has not been observed in the Raritan formation which underlies, nor in the Chesapeake formation which overlies, this series of glauconitic deposits.

DESCRIPTION OF THE FORMATIONS.

Matawan formation (Clay Marls).—On account of the extensive and typical development of the Clay Marls on the shore of the Raritan Bay in the vicinity of Matawan Creek, and along the banks of the latter stream, the name Matawan formation is proposed for the deposits of this horizon.

The greensand is a less pronounced feature than in the overlying formations. The deposits consist for the most part of dark colored clays with interbedded layers of sand, the latter becoming very pronounced in the upper portion of the formation. At some points beds of greensand appear, but they are generally

thin and of very narrow geographical extent. The deposits are largely fragmental, with here and there an admixture of carbonate of lime derived from the shells of organisms.

The most extensive section is afforded by the bluffs on the shores of the Raritan Bay, between the mouth of Cheesequake Creek and the Navesink Highlands. From this point the formation extends southwestward across the state, the best exposures being found along the stream channels entering the Delaware River from the east. Both along Crosswicks and Pensauken Creeks the strata are highly fossiliferous, at the latter locality over a hundred species having been identified. In the main the forms are the same as those in the overlying Navesink formation, although some are distinctive.

From the surface outcrops the Matawan formation has been estimated to have a thickness of 275 feet.

The most striking differences both in the character of the materials and the thickness of the beds, are shown by well borings along the line of dip. A recent boring at Asbury Park penetrated the Navesink formation (Lower Marl Bed) at 400 feet, beyond which for a distance of over 400 feet typical Clay Marls were encountered. From 750 to 780 feet glauconitic layers were found, while the deposits in general are finer and more regularly stratified than in the surface outcrops to the westward.

Navesink formation. (Lower Marl Bed).—The lower Marl Bed has an extensive development throughout the region of the Navesink Highlands, in the vicinity of the village of Navesink, and along the north bank of the Navesink River, so that the name of Navesink formation may be with propriety employed.

Greensand forms the distinguishing feature of the deposits. The lower portion is frequently quite sandy, in this respect showing the change from the sandy layers of the upper portion of the Matawan formation, upon which it lies conformably, to the typical greensands of the Navesink formation. The upper portion again shows the presence of much land derived material; it is highly argillaceous and just at the top frequently arenaceous. The greensands along the thinned out western edge of the Navesink forma-

tion have been oxidized to so great an extent that their separation from the red sands of the Redbank formation is often a difficult matter.

On account of the great economic importance of the greensand beds of the Navesink formation frequent pits have been dug into it all along its line of outcrop from the northern to the southern end of the district. As a result the strata may be studied to great advantage.

A magnificent exposure is found in the great bluffs of the Navesink Highlands facing the Raritan Bay, while excellent sections are to be found along many of the streams that cut through the formation. The beds are highly fossiliferous and the most varied fauna in the New Jersey Cretaceous is found at this horizon. Between 300 and 400 species have been described.

The Navesink formation has a pretty constant thickness of 40 feet, although locally ranging from 30 to 60 feet. The deposits have been found to be remarkably persistent in character both along the strike and dip, so far as they have been examined.

Redbank formation (Red Sand).—The bright red sands of this formation afford one of the most striking features of the country throughout the marl district. They are extensively developed in the vicinity of Redbank, and on that account the name Redbank formation is proposed for the deposits of this horizon.

The strata are glauconitic throughout, although the great preponderance of coarse arenaceous sediments has facilitated the oxidation of the greensand, changing the green color of the beds to red or brown. The lower portion of the Redbank formation is often composed of black sand or sandy clay, while at the top of the formation there is an indurated clayey layer generally of a distinctly greenish color. This hardened stratum has had an important influence in the development of the topography of the marl district, and especially in the extreme north the higher hills are largely due to its presence. The fossils are in the main the same as in the preceding formations, but on account of their poor preservation have not up to the present time been very fully studied. The indurated layers have afforded the greater number.

The formation has a rather constant thickness of 100 feet.

Rancocas formation (Middle Marl Bed).—The Middle Marl Bed is not as prominent a feature in Monmouth county where the type localities for the other formations are found as farther southward. The Rancocas Creek in Burlington county cuts through the Middle Marl Bed exposing a full sequence of the deposits of that formation, while in the neighboring area extensive exposures of the strata are found.

The formation is largely a greensand, although much more highly glauconitic in the lower than in the upper half of the formation. Although the lower half is largely a pure greensand, it becomes in some portions of the state very argillaceous toward the base, forming the so-called "chocolate marl," while toward the top it becomes crowded with shells, the upper two feet characterized by the presence of *Terebratula Harlani*, the most persistent fossiliferous zone in the state. The upper half of the formation is highly calcareous, frequently appearing as limestone ledges, known as "yellow limestone," and often containing as much as 80 per cent. of carbonate of lime. It is extremely fossiliferous, and has afforded many beautifully preserved specimens of Bryozoa, Echinodermata and Foraminifera. The fossils are, in the main, different from those in the underlying formations.

The strata reach a thickness of about 45 feet.

Manasquan formation (Lower portion of the Upper Marl Bed).—The name Manasquan Marl was in an earlier publication made to include the Yellow Sand, together with the "green sand" and "ash marl" of the Upper Marl Bed of Professor Cook. For that horizon the term Manasquan formation is retained. It is typically developed in the valley of the Manasquan River and its tributaries.

Like the preceding formation it is essentially a greensand throughout, although distinctly quartzose in the lower part, and at times argillaceous in the upper layers. The fossils so far as observed are confined exclusively to the more highly greensand member, but the number of species is not large. The high per-

centage of soluble phosphates in the Manasquan marl has long given it a high reputation as a fertilizer.

The thickness of the strata has been estimated at 65 feet.

Shark River formation (Upper portion of the Upper Marl Bed).—The term Shark River Marl was earlier employed by the writer to embrace the "blue marl" of the Upper Marl Bed, which has been generally referred in recent years to the Eocene, although the beds are conformable with the underlying strata concerning whose Cretaceous age there is apparent unanimity of opinion.

The Shark River formation is a characteristic greensand with a slight admixture of argillaceous materials, while a hardened and stony layer is found directly at the top. The fossils are numerous, but cannot be readily compared with those from the Eocene areas to the southward. The strata of the Shark River formation have not been found at any point to exceed 12 feet in thickness.

The Shark River formation closes the series of greensand deposits. It is unconformably overlain by strata of a very different character which show evidence of marked mechanical disturbances and rapid deposition.

Throughout the entire sequence of deposits just described, the presence of greensand has been the most distinguishing feature. Its origin is therefore a matter of great importance to the understanding of the several formations, and will be briefly discussed.

ORIGIN OF GREENSAND.

Greensand has been found in greater or less amounts at nearly every geological horizon, from the Cambrian down to the present time. It is not an original deposit of clastic origin, but secondary in character. An examination into the conditions of production which surround those deposits forming upon the floor of existing seas will afford an explanation of the strata of past geological time.

Great light has been thrown upon this subject as a result of he deep-sea dredgings which have been made in recent years

by the vessels sent out on scientific expeditions by the various governments of Europe and our own. The most important of these expeditions has been that of the Challenger, sent out by the British government in the years 1872–76. In the report upon the Deep Sea Deposits recently published as a result of that expedition, Professors Murray and Renard, the authors, present the latest results upon the character and distribution of greensand, and, at the same time, propose a theory to account for the chemical changes which have taken place to produce the mineral glauconite which characterizes all greensand deposits.

A typical greensand is composed of glauconite associated with greater or less amounts of land-derived material. Among the more common minerals thus found are quartz, feldspar, hornblende, magnetite, augite, zircon, epidote, tourmaline and garnet, together with fragments of the continental rocks, such as gneiss, mica-shist, granite, diabase, etc. A variable amount of calcareous matter derived from the shells of organisms is also present.

The glauconite occurs in minute grains, seldom exceeding 1 mm. in diameter, although they may become agglomerated into nodules several centimeters in diameter by means of a phosphatic cement. The grains are always more or less rounded, and at times mammillated, with irregular surface outline. They are generally black or dark green in color, but become brighter green upon being crushed. The surface of the grains is sometimes covered with fine punctures, while at other times it is smooth and shining. Some of these glauconitic grains are distinct internal casts of foraminifera, and of other calcareous shells, but more often they only reproduce indistinctly the form of the chambers, or show no definite connection with the organisms in which they originated.

It is estimated that greensand deposits cover approximately 1,000,000 square miles of the sea floor. They are found limited to those portions adjacent to the coasts, and, for the most part, along the higher parts of the continental slopes where land-derived materials are deposited in perceptible, yet small amounts. The production of glauconite seldom reaches to greater depths

than 900 fathoms, and most commonly takes place between 100 and 200 fathoms. The entrance of large rivers into the sea or the prevalence of strong currents would tend to interfere with its formation, so that the area of distribution of greensand is seldom continuous for great distances.

Although greensand is not known to be formed except in the presence of land-derived materials its production is accomplished through the intervention of foraminifera. Their connection with the formation of glauconite was first shown by Ehrenberg[1] in 1855 as the result of a study of greensand from many deposits in Europe and America. Professor Bailey[2] the succeeding year stated that the formation of greensand is likewise taking place on the floor of existing seas, and under the same conditions that existed in past geological ages.

According to Murray and Renard the chambers become filled with muddy sediment, and "if we admit that the organic matter enclosed in the shell, and in the mud itself, transforms the iron in the mud into sulphide, which may be oxidized into hydrate, sulphur being at the same time liberated, this sulphur would become oxidized into sulphuric acid, which would decompose the fine clay, setting free colloid silica, alumina being removed in solution; thus we have colloid silica and hydrated oxide of iron in a state most suitable for their combination." The potash which is necessary to complete the composition of glauconite may be derived from the decomposition of the fragments of crystalline rocks or their common constituents, orthoclase and white mica.

Two conditions then are requisite for the production of glauconite, first the deposition of mineral particles of land-derived origin; and second, the presence of foraminifera. In the absence of either the production of greensand will not take place. It is further seen that the formation of greensand is retarded and finally ceases altogether as the amount of deposition of land-derived materials increases adjacent to the coasts. Only

[1] Abhandl. d. k. Akad. d. Wissenschaften zu Berlin, 1855, pp. 85–176.

[2] Boston Soc. Nat. Hist., Proc., Vol. 5, 1856, pp. 364–368.

then within circumscribed limits, which are constantly subject to modification, is the production of greensand possible.

GENESIS OF THE DEPOSITS.

The opening of the Cretaceous period along the Atlantic border witnessed the deposition of large amounts of irregularly stratified sands and clays together with beds of gravel in the vicinity of the coasts. It was a period of great mechanical disturbance over the area of deposition, and both the physical and faunal characters of the strata point to the close proximity of land, while enclosed basins doubtless existed for a portion of the time.

With the opening of the epoch of greensand deposition, as represented in the Matawan formation, much the same conditions at first prevailed. Alternating beds of sand and clay were laid down, but gradually the coarser elements disappeared, deposition became less rapid and greensand was locally developed. The conditions for greensand production were not widely extended nor long existent, for successive periods of rapid and slow accumulation of materials continued to the close of Matawan deposition.

With the advent of the Navesink epoch land-derived materials became greatly reduced in volume and shortly ceased almost altogether, so that throughout the area of deposition there was formed at this horizon some forty feet of highly glauconitic greensand. Toward the close of this period terrigenous deposits became more pronounced, but the production of glauconite did not altogether cease.

With the opening of the next epoch, represented by the Redbank formation, dark sands in which the proportion of glauconite was very small were at first deposited. Throughout the whole series of beds glauconite is found distributed in greater or less amounts, but at no time did its production reach the prominence that it had during the previous epoch. The marked admixture of coarse elements throughout most of the deposits rendered them later subject to the ready percolation of water by which

the complete oxidation of the glauconite was accomplished. Toward the close of the Redbank epoch finer sediments prevailed, and there is every evidence that land-derived materials found ingress to the area of deposition in gradually lessening amounts.

The succeeding Rancocas epoch was a time of slow accumulation of continental materials so that the production of glauconite went on unhindered. During the latter portion of the epoch, however, there must have been a great profusion of animal life, for the deposits show a marked admixture of carbonate of lime, while in many instances the shells are still in an excellent state of preservation. The formation of glauconite was not interrupted, although its relative proportion is at times much diminished by the great amount of carbonate of lime which may in some instances reach eighty per cent. of the whole.

The Manasquan epoch was characterized throughout by the constant formation of greensand beds, although land-derived materials in considerable amounts reached the area of deposition during the early portion of the period.

No very marked changes apparently affected the region toward or at the close of the Cretaceous, but the same conditions persisted on into the Eocene, as shown in the Shark River formation, during which period similar deposits with very different types of animal remains were accumulated. At the close of the Shark River epoch the conditions favorable for the formation of greensand ceased, not to be again revived during the period of formation of the coastal deposits in New Jersey.

The succeeding epochs gave proof of much shallower waters, while the ancient Cretaceous-Eocene sea floor frequently stood above sea level and along its landward portions constantly lost as the result of erosion. As the land rose higher and higher in late geological history further inroads were made until the deeper portions of the ancient sea bottom were exposed by the forces of denudation.

SOURCE OF THE MATERIALS.

The source of the materials which constitute the several formations of the coastal region of New Jersey has not been

altogether satisfactorily explained, although the deposits indicate that they were largely derived from crystalline rocks.

That the red sandstones and shales of the Jura-Trias (Newark Formation) which adjoin the coastal series upon the landward side have not been the source of the materials is a striking fact, and one which has been largely commented on in the past. By some it has been supposed that an area of crystallines must have existed to the eastward to afford the materials for the deposits under consideration. A study of the drainage of the Jura-Trias belt which separates the coastal formations from the area of crystalline rocks beyond, is of interest, however, in showing the probable extension of the coastal deposits quite over the red sandstones and shales of the Jura-Trias to the border of the crystalline region and at the same time affords a sufficient explanation for the absence of sediments derived from the Jura-Trias itself. The evidence for this has been recently presented by Davis[1] in the National Geological Magazine, and the reader is referred to the article for a fuller explanation of the subject.

Accepting the explanation of Davis as highly probable we may look for the source of the land-derived materials out of which the greensand deposits are formed, in northwestern New Jersey, eastern Pennsylvania and southeastern New York, in a portion of that tract of crystalline rocks which stretches along the eastern side of the continent. A separation of the mineral constituents of the greensand deposits shows a preponderance of both the constituent and accessory minerals which characterize those rocks. It seems conclusive, therefore, that the area mentioned was the source of the materials for the greensand deposits of eastern New Jersey.

TAXONOMY.

The geological formations of New Jersey early attracted the attention of geologists, and Professor Peter Kalm[2] of Sweden,

[1] Nat. Geog. Mag., Vol. II., No. 2, pp. 1-30, 1890.

[2] En Resa til Norra America 8vo. 3 vols. 1753-61, Stockholm. Translations in English by J. R. Forster 1st. Ed. 1770-71, 2nd. Ed. 1772, another Ed. in J. Pinkerton's Voyages, Vol. 13, 1812; in German by J. H. Murray, 1754-64; in French by L. W. Marchand, 1859.

who was sent out in 1749 under the auspices of the Royal Academy of Sciences to make a study of the various branches of natural history in America, presents many interesting observations concerning the deposits under consideration. He spent much of his time in New Jersey.

In 1777, Dr. Johann David Schoepf[1] of Germany, visited America in order to study the geological features of the eastern portion of the continent. His observations and comparisons of the coastal plain formations, especially of New Jersey, mark considerable advance over those of Kalm. The importance of his investigations have not been very generally recognized by later writers, but he showed a remarkably keen insight into the geology of eastern America which was lacking on the part of some of his successors.

The first attempt at a correlation of the deposits of New Jersey with the geological column then established in Europe was made by William Maclure[2] in 1809, in his "Observations upon the Geology of the United States." In this publication the coastal deposits of New Jersey are collectively referred to the "Alluvial formation," the fourth of the main divisions of geological strata proposed by Werner. The work was subsequently revised and enlarged, appearing in book form in 1817.[3]

Professor John Finch was the first to propose a division in the coastal plain deposits of New Jersey. In his "Geological Essay on the Tertiary Formations in America" he states that what has been called the "Alluvial formation" by earlier writers "is identical and contemporaneous with the newer Secondary and Tertiary formations" of other portions of the globe.

A few years subsequent to this, Professor Lardner Vanuxem[4] through his friend Dr. S. G. Morton, presented the criteria for a

[1] Beiträge zur mineralogischen Kenntniss des östlichen Theils von Nord Amerika und seiner Gebürge. 8vo, 1787, 194 pp. Erlangen.

[2] Amer. Phil. Soc. Trans. Vol. 6, 1809, pp. 411–428. Translation in Journal de Physique, Vol. 69, 1809, pp. 204–213 and Vol. 72, 1811, pp. 137–165.

[3] Philadelphia, 8vo, 130 pp. Also in Amer. Phil. Soc. Trans. new series, Vol. 1, 1817 pp. 1–92; and Leonard's Zeitschrift, Band 1, 1826, pp. 124–138.

[4] Amer. Jour. Sci. Vol. 7, 1824, pp. 31–43.

more complete and definite recognition of the several members of the coastal series in which both the Cretaceous and Tertiary formations were described in some detail.

With the establishment of the official geological survey of New Jersey under the direction of Professor H. D. Rogers[1] the first attempt was made at a detailed differentiation of the local deposits. The formations, beginning at the bottom, were designated as follows: *Clays and Sands*, *Greensand*, *Limestone*, *Ferruginous Sand*, and *Brown Sandstone*. Although the various members were not clearly defined and widely different materials were included under the same division, yet the easterly dip of the strata was observed and the broader distinctions in the stratigraphy of the area were recognized.

Dr. T. A. Conrad,[2] in 1848, first suggested that the upper portion of the greensand series was of later age than the Cretaceous, a conclusion which he more fully elaborated at a later date.

The second geological survey of New Jersey, organized in 1854, under the direction of Wm. Kitchell, had as assistant geologist, George H. Cook, who a few years later became himself State Geologist, a position he held for over twenty-five years, until his death in 1889. He devoted from the first much attention to the greensands, and his classification of the strata has met with wide acceptance. It is elaborated in much detail in the Geology of New Jersey, published in 1868. The series of formations as recognized by Professor Cook is as follows, beginning with the oldest: *Plastic Clay*, *Clay Marls*, *Lower Marl Bed*, *Red Sand*, *Middle Marl Bed*, *Yellow Sand*, and *Upper Marl Bed*. Subsequently, Professor Cook[3] considered that an unconformity existed between the Eocene and Cretaceous members of the Upper Marl Bed.

There is no area in this country where the several formations have been studied more with reference to their own characteristics

[1] Philadelphia Acad. Nat. Sci. Jour. Vol. 6, 1828, pp. 59–71.

[2] Philadelphia Acad. Nat. Sci. Jour. new ser. Vol. 1, 1848, p. 129. Philadelphia Acad. Nat. Sci. Proc. Vol. 17, 1865, pp. 71, 72.

[3] Report of the State Geologist for 1883, pp. 13–19.

and less with reference to the supposed similarity of faunas and deposits with other and particularly European horizons.

The difficulties in the way of extended correlation are so great that for purposes of study it is often necessary to apply local names to the several formations of a particular district. There are, beyond a doubt, objections to the multiplication of names of geological horizons and already accepted terms should be employed as far as possible, but very frequently they prove to be inadequate for stratigraphical requirements. Such is the case in the New Jersey area.

Outside of the major divisions of the geological column it is impossible to employ the terms of European authors. All such attempts have, upon critical examination, failed to stand the test. The lithological and faunal characteristics show such wide variations that definite correlations of minor horizons are impossible. The geological formations of America must be studied first upon their own merits and only after a complete understanding of them has been gained can satisfactory comparisons be made with foreign areas. A detailed correlation of the New Jersey formations with European will therefore not be attempted.

Again the conditions under which the strata of the different portions of this country were deposited, are so varied that the same terms are not applicable over wide areas. The formations of the Interior are in a marked degree dissimilar from those of the Atlantic border, and even throughout the coastal plain very considerable differences are found in its various portions. Correlations of more satisfactory character can be made here than with foreign areas, but many obstacles debar the geologist from the full consummation of his task. It is possible to show in a general way the equivalency of the deposits upon the Atlantic border with those in the Gulf, the Interior, or on the Pacific coast, although in the case of individual formations such comparisons are of doubtful character.

Dr. White[1] in his admirable essay upon the Cretaceous of North America, discusses very critically the evidence for the

[1] Bull. U. S. Geol. Survey, 82, 1891, 273 pp.

correlation of the New Jersey greensands, but does not attempt to separate the individual members of the series beyond the reference of the upper member to the Eocene, as was also done by the writer[1] in his report upon the Eocene. It is impossible however, to satisfactorily correlate this upper member of the greensand series with the Eocene elsewhere, and it is not known how much of that horizon is included in it. It has been generally thought to represent the Lower Eocene of other regions. Concerning the other formations of the greensand series there seems to be little doubt of their reference to the Upper Cretaceous, although they probably do not include its earlier portions. Many of the same species have been found in the Cretaceous areas of the South Atlantic and Gulf States. Stanton[2] has recognized thirty-five species as identical in Alabama, eighty-six in Mississippi, and fifty-four in Texas. Some of the species which are very much restricted in the New Jersey area, appear to have a greater vertical range in the Gulf region. It is therefore very difficult to delimit equivalent horizons. It is not unlikely that a fuller knowledge of the formations may render it possible to make more detailed correlations, but at present it is impossible.

On these grounds, therefore, an independent classification of the New Jersey deposits is demanded. The objections to the use of lithologic terms have been already cited, as well as the grounds for employing the place names adopted.

GENERAL CONCLUSIONS.

The greensand strata of New Jersey constitute a conformable series of beds aggregating nearly 550 feet in thickness. During the Matawan epoch, when fully one-half of these deposits were being laid down, land-derived materials reached the sea in large amounts, frequently interfering with the formation of glauconite, which is much less prominent at this horizon than later. During the succeeding epochs the production of greensand was much

[1] Bull. U. S. Geol. Survey, 83, 1891, 173 pp.

[2] Bull. U. S. Geol. Survey, 82, 1891, p. 84.

more constant, although there were times when it became greatly reduced in amount on account of the advent of large amounts of sand and mud from the adjacent coasts.

From the known conditions requisite for the production of glauconite upon the bed of existing seas, and the possible position of the coast line in Cretaceous time, it seems likely that the greensands now outcropping at the surface were laid down from fifteen to thirty miles off the coast. Frequent changes of level no doubt took place, but the variations in the character of the deposits were probably quite as much due to fluctuations in the currents as to pronounced changes in the position of the coast line.

The marked thickening of the Matawan formation seaward, as shown by the well-boring at Asbury Park, is of interest as indicating the more permanent character of the deposition outside the area of mechanical disturbance such as characterized the shallower portions of the Matawan sea floor.

The alterations which have taken place in the exposed portions of the deposits are oftentimes widespread, and in the case of the indurated layers at the top of the Redbank formation have determined to a large extent the topography of the greensand district.

Many interesting problems are presented for further study, but it is hoped that this paper may contribute somewhat to a clearer understanding of greensand deposits in general, and those of the New Jersey area in particular.

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THE NATURE OF COAL HORIZONS.

THE Coal Measures of the Mississippi valley occupy an area of more than 120,000 square miles. They extend in an almost unbroken field from the western flank of the Appalachians on the east to beyond the Missouri river on the west. Separating the area into two somewhat unequal parts is the Mississippi river along the course of which are exposed older rocks. The Coal Measures may have been at one time continuous over the central portion, but the outcrops of the more ancient rocks along the borders of the Mississippi is probably not due entirely to unaided erosion but in part to slight folding, an anticlinal axis coinciding approximately with the line of the great river.

The geological history of the eastern and western areas, which are sometimes called respectively the Central and the Western Interior coal fields, is probably similar, though in some particular phases there is a divergence which dates back prior to the close of the Lower Carboniferous. The northern portion of the Coal Measures west of the Mississippi forms a broad bay-like expansion opening to the westward. Beyond the Missouri river the strata are hidden from view by newer sediments. The most productive portion of the Western Interior coal field is a marginal zone extending from northcentral Iowa southeastward to northeastern Missouri, thence sweeping to the westward around the Ozark uplift into Indian Territory and continuing on into central Texas. The interior portion of the bay-like expansion of Coal Measures is as a general thing unproductive, though a few thin seams of coal do occur.

Everywhere throughout the region the stratigraphical details present great simplicity, being almost free from the effects of orographic movements. The lithological characters of any one locality are repeated again and again in the same monotonous

succession. The faunal and floral features are practically identical from one end of the great coal basin to the other.

The greatest interest, economically and geologically, in the Carboniferous basin centers around the coal deposits. Their disposition perhaps comes first in importance, both from the standpoint of the operator and of the geologist. The subject is certainly one of wide-reaching import.

There is now abundant evidence to show that the Western Interior coal field at the time of deposition was for the most part a broad, shallow basin opening to the westward into the great continental sea which then occupied most of what is now known as western North America. That the Coal Measures of the region were laid down during a period of gradual, prolonged, though often checked, subsidence is evidenced by all stratigraphical and lithological details, as well as by the characteristic faunal peculiarities. That the coal beds originated largely in coastal swamps of limited breadth but, with some interruptions, of very considerable length, stretching out near sea level for long distances and sending out minor extensions into the old rivers and estuaries is fully warranted by the facts disclosed everywhere. On the low, slowly sinking shores there prevailed at certain times a similarity of physical conditions especially favorable to coal formation. During these intervals unusual amounts of coaly material were allowed to accumulate and to be preserved in places, the period being preëminently one of coal growth, at least for a given province. The great stratigraphic plane marking each record may be appropriately termed a "Coal Horizon."

In stratigraphy, a geological horizon is a level recognizable over a considerable geographical extent, having a more or less well defined stratigraphical position, distinctive as to lithological features and characterized by a particular set of fossils. The term in a broad sense is almost equivalent to formation, and has been used as indefinitely. In its more limited meaning it is applied properly to a minor part or zone of the smallest stratigraphical unit having a commonly accepted specific name. Un-

derstood in the same way, a "Coal Horizon" represents an even more limited expansion, where coal forming materials have accumulated. Practically it is one of the greater planes of sedimentation, marking a distinct episode in the deposition of a series of strata. Theoretically it represents not a phenomenon, but rather a set of conditions, a period during which the physical circumstances were similar over a considerable marginal portion of a geological province. From an economic standpoint it stands not for a continuous bed of mineral fuel, but a stratigraphical level where workable beds are more likely to occur than elsewhere, and where the coal is to be especially sought for in a wide belt fringing a great coal basin. It is not to be inferred, then, that the mineral is equally developed on a given

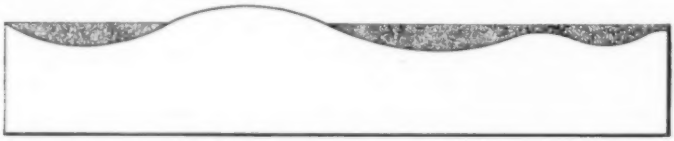

FIG. 1. Coal Horizon at time of formation; parallel to shore line.

horizon in all portions of this marginal border. In some places the accumulations of plant remains are much greater than in others; limited basins and troughs of unusual thicknesses are there found. Elsewhere the old vegetable materials are meagerly represented; only thin seams of coaly matter are there preserved. Wide intervals of sandstone and shale often separate adjoining basins, or ancient land elevations may cut off one area from another. (Figure 1). Yet, through all of the many irregularities of deposition and subsequent deformation there are nevertheless discernible, certain levels quite well defined at which coal beds are very much better developed than at others; clearly marked coal horizons they are, broad in extent and capable, in the case of the greater ones under favorable circumstances, of being traced over a large part of a given Coal Measure province. The coal may not be present in a continuous seam over the whole border district and probably never is; but along much of the

margin of the coal horizon, which at one time must have stood near the sea level for a considerable period, are innumerable basins separated from one another perhaps, yet to all appearances formed contemporaneously. Now they may thicken into sharply defined lenticular beds; now thin out to mere films, or disappear altogether; and again further on they assume the form of extensive lens-shaped sheets. During deposition, as subsidence became too rapid or the sea too deep for the proper accumulations of vegetable material, sediments were carried in covering the plant beds. Or, if elevation took place the old swamps, already shut off from free access to the sea, were subject to the agencies of denudation and were partially or entirely removed. As favorable physical conditions again set in the same course of events might be repeated.

In considering the relations of the different coal horizons to one another an approximate parallelism may be made out. Not a strict parallelism of the nature which Andrews[1] claimed to be true in Ohio, and which Newberry[2] subsequently stated to be entirely unsubstantiated by facts, but an approximate parallelism in a broad way.

There was apparently a germ of truth in the idea of the first named author, though he was probably unfortunate in the choice of a name for his theory. Moreover, none of his writings indicate that he understood the problem in the way that recent investigations reveal it. His statements all seem to show that, while he was manifestly on the right path, only one side of the subject had been presented to him, just as, quite recently, the question has been discussed from the opposite extreme. Andrews' views are perhaps best expressed in the following paragraph taken from his paper[3] on the subject:

"I have never found the slightest proof of the formation of a seam of coal over hills or high grounds. The parallelism of the seams, of which further mention will be made, forbids it.

[1] Geol. Sur. Ohio, Vol. I, p. 348. Columbus, 1873.

[2] Geol. Sur. Ohio, Vol. I, p. 169. Columbus, 1874.

[3] Geol. Sur. Ohio, Vol. I, pp. 348–350. Columbus, 1873.

. . . . . So far as my observations go, I have never found an instance where two distinct seams of coal came together or, conversely, where a seam became divided and its parts continued to diverge for a long or indefinite distance. It is not uncommon to find, in a seam of coal, the proof that the coal marsh had in it local depressions, which were filled with sediments, making a soil on which new vegetation grew, and thus the seam shows two parts, separated by fire clay sometimes several feet thick; but in every instance when traced I have found the parts to reunite. The two parts never diverge indefinitely. From these

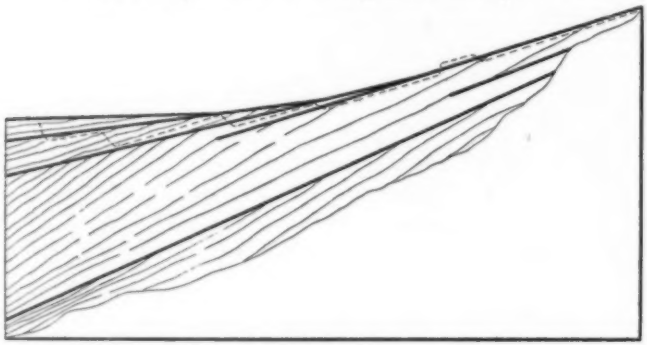

FIG. 2. Stratigraphy of Coal Beds.

statements we may infer a general law of parallelism. Such law is in harmony with the belief of the most careful observers, that our productive Coal Period was characterized by great quietness and freedom from violent local disturbances."

This describes the apparent condition of things in Ohio. The same with minor modifications and explanations may be regarded as according fairly well with the facts observed in the Iowa-Missouri coal field.

On the other hand there are many who, with Newberry, have directly opposed any approach to the recognition of the parallelism of coal veins. Among the latest opinions on this side of the discussion is one expressed by Winslow,[1] who in considering

[1] Geol. Sur. Missouri, Rep. Coal, pp. 28–30. Jefferson City, 1891.

the stratigraphy of Missouri coal seams is led to believe that the different veins diverge from one another in a manner best explained by the preceding diagram, the dotted line representing post-Carboniferous erosion. (Figure 2).

These conditions also accord in the main with the facts observed in all the Western coal fields.

An attempt to harmonize the two seemingly very divergent and even contradictory theories is apparently fruitless. But a more careful examination of the subject shows that the two theories are manifestly not based on facts taken from the same point of view, but from quite different positions. Andrews' idea may be taken as representing a cross section of the coal bearing strata taken parallel to the general course of the shore ; Winslow's a section at right angles.

In districts where mountains are being elevated, orographic movements in the earth's crust continue to be felt for long distances from the line of maximum disturbances. If a great sea or an ocean occupies a region affected to a moderate extent by the oscillations, an extended shore line trends approximately with the axis of the mountain system, for the more important minor corrugations commonly run in similar parallel lines. The direction of maximum change in the inclination of strata is therefore at right angles to the axes of the folds, and hence in a broad way perpendicular to the shore line. The direction of minimum change in tilting is, under ordinary conditions, the same as the axes, or parallel to the shore. Bearing these suggestions in mind geological cross sections, under favorable circumstances of examination, would show a general parallelism of coal beds when made in one way ; a decided tendency to non-parallelism when constructed in the other.

Granting, then, an old, uneven land surface, such as is known to have existed in Carboniferous times in the upper Mississippi basin, with the waters of the sea and the marginal maritime flats gradually creeping inland, it would naturally be expected that in the case of any one of the marshy plains skirting the shores for any great distance there would be a very tortuous boundary on

the land side and a somewhat less sinuous line on the seaward side; on the one hand were probably low hills and uplands sending out spurs here and there which cut off one marsh from another and often allowing long open stretches of low upland to reach out even to the waters of the sea itself; on the other hand were often narrow coastal plains rising scarcely above sea level, but, to a great extent, shutting off very effectually the saline waters from the swamps. Viewed areally, the productive portion of one of the great coal horizons is a wide irregular zone running in a tortuous course around a more or less extensive portion of the margin of a coal bearing basin included within the limits of a geological province. Examined at the present time coal horizons present, with all the irregularities of original deposition, subsequent change and deformation, a quite different aspect from the ideally perfect level of the ancient surface or zone which existed during the period of formation. In one direction, parallel to the shore, there is a series of minor saucer-shaped basins strung along on about the same great stratigraphical plane. They may rise or fall as the other strata change in inclination. They may be separated by wide stretches of sandstone or shale, or may come together in places. In the different basins the original vegetable materials in becoming compact shrink most in bulk in the middle, thus allowing the margins to remain considerably higher than the center. This is more noticeable in small basins than in large ones. Then, too, the fact that the direction of minimum movement in the changes of level was, as has been shown, parallel to the prevailing trend of the shore does not preclude even in this direction a certain amount of tilting of the strata either by the rising or the sinking of one portion of the shore more rapidly than another; or by the passage of some of the minor folds in directions not strictly harmonious with the general movement.

When a new cycle of vegetable accumulation took place the coastal swamps would again spread out at sea level, but not necessarily on planes exactly parallel to the horizon previously formed. Horizons which were separated to very considerable distances by

shales or other strata, probably are rarely exactly parallel to one another, or if so, the parallelism is purely coincidental. There are many causes which in places lead to the non-parallelism of the coal horizons. The original bottom of the sea may have been very uneven, as is well shown in the very irregular surface of the Saint Louis limestone on which the Coal Measures were laid down. Or, in two different seams the inequalities may be great, the extremes often occurring in the same locality, and thus presenting a much greater apparent unevenness than really exists. Erosion or currents may have altered the position of the seams or parts of them. The top of the seams which were originally level became subsequently depressed in the center more than at the margins. There are also other causes tending to widen the seeming discrepancies. (Figure 3).

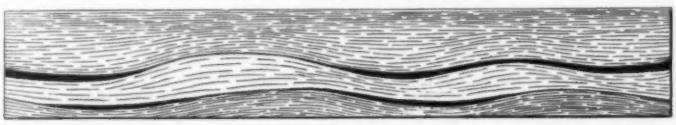

FIG. 3. Coal Horizon as it now exists; parallel to shore line.

In another direction, at right angles to the old shore, the minor basins along the different horizons may appear to show no tendency to parallelism at all. The approach to the parallel condition is inversely proportional to the amount of deformation occurring in the region at the time of the formation of the coal beds. Instead also of the seam being continuous for a considerable distance across the coal basins, as may be inferred from Winslow's graphic representation, the productive coal strata should be confined to a limited marginal area and the coal horizon would only extend into the interior as a great stratigraphical plane, not easily recognizable perhaps, nor with any of the mineral itself to mark it. (Figure 4).

The conditions described apply particularly to the coal fields of Iowa and Missouri, where comparatively few disturbances of the strata have taken place. The relations are relatively simple. But

in Ohio and Pennsylvania, as the mountains are approached, the structure increases rapidly in complexity, until in the highly folded and faulted districts attempts to follow out the original state of things may become utterly hopeless.

The majority of the larger coal deposits of the Western Interior field may be considered then as having been formed in swamps skirting a great shallow gulf, the extent of the produc-

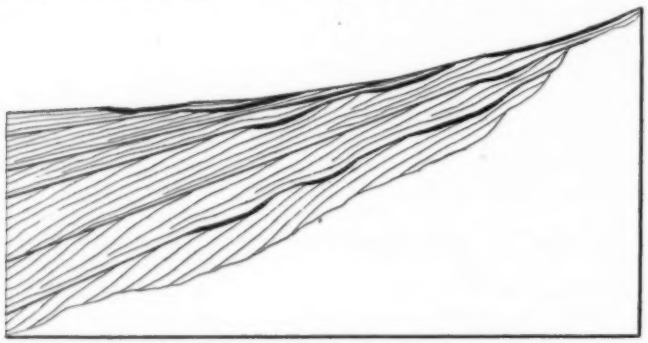

FIG. 4. Coal Horizon viewed at right angles to shore line.

tive portions of the different horizons being in a measure dependent upon the length of time the physical conditions were favorable to coal formation. Many short minor episodes doubtless existed between the larger ones, during which comparatively small accumulations of vegetable material took place.

Another fact to be taken into consideration is that all the coal of the region was not formed in marine swamps, but that some of the minor basins were doubtless originally a very considerable distance from the sea, while certain others were formed where open sea conditions prevailed largely. A few seams also appear to have been formed as drift materials in estuaries at the mouths of streams.

CHARLES ROLLIN KEYES.

THE ARKANSAS COAL MEASURES IN THEIR RELATION TO THE PACIFIC CARBONIFEROUS PROVINCE.[1]

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INTRODUCTION.

MARINE fossils of Coal Measure age were found by the Geological Survey of Arkansas in eighteen places, fourteen in the lower division and four in the upper. These localities extend from Independence county westward to Indian Territory, and

[1] From an unpublished report of the Geological Survey of Arkansas, by permission of the Director, John C. Branner.

give a total of 48 genera and 78 species, 31 species in the Lower Coal Measures, and 51 in the Upper, with 4 species common to both.

It is not thought that this small number of species represents the entire fauna, or that only four species are common to the two divisions, for the collections were much too scattered and too meager to exhaust the possibilities.

But the fauna is a poor one, such as one would expect to wander in from deeper waters, whenever a slight subsidence had made the shallow water a little more habitable. The fauna could not become well established, because the conditions soon reverted to their old state, and the inhabitants of the seas were forced to migrate or were exterminated.

There is, therefore, no gradual transition here from the fauna of the Lower Carboniferous limestone, since the presence of these fossils depends on the transgression of the sea on land areas, and the fossils of the Lower Coal Measures are just as different from those of the Lower Carboniferous as are those of the Upper Coal Measures.

No successful division of the Coal Measures into zones has ever been carried out, and in the present state of our knowledge it cannot be done. This makes the correlation of distant localities difficult, since the vertical range of species in the Coal Measures is very little known. Therefore, the range of the species in Arkansas cannot be given any closer than the two great divisions of the Coal Measures.

COMPARISON WITH THE PERMO-CARBONIFEROUS OF KANSAS AND NEBRASKA.

The fauna of the Upper Coal Measures of Arkansas has a strong resemblance to that of youngest Paleozoic beds of Kansas and Nebraska, described as Permian by Professor Geinitz.[1]

F. B. Meek redescribes this fauna,[2] and comes to the conclusion that the rocks in question are not to be referred to the Per-

[1] "Carbonformation und Dyas in Nebraska."

[2] Final report U. S. Geol. Survey of Nebraska, etc., pp. 128 *et seq.*

mian, because he can find no paleontologic or stratigraphic break to separate them from the Carboniferous. He finds 16 genera characteristic of the Carboniferous, and 7 genera not thought to antedate the Permian in Europe, but associated with genera not thought to occur later than the Carboniferous. Meek[1] says that *Fusulina*, which occurs in great numbers in the uppermost Carboniferous beds of Nebraska, is considered in Europe to be mainly if not exclusively a Lower Carboniferous genus. In this, however, he was mistaken; his opinion dates from a time when most geologists were inclined to place all Carboniferous limestone in the Lower Carboniferous. But it is now known that the Carboniferous limestone occurs in the Upper Carboniferous about as often as in the Lower, and the *Fusulina* limestones of Sicily and Russia grade over into beds of undoubted Permian age. This is also true of corresponding beds in the upper part of the Carboniferous of Texas. In fact the *Fusulina* beds are always either Upper Carboniferous or Permian, in eastern Europe and Asia, and nearly always in America.

Although undoubtedly believing in continuity of life and formations, Meek seems to have based his reasoning on the old idea of catastrophies, since he thought that the absence of a paleontologic or stratigraphic break was a sufficient reason for calling the beds in question Upper Coal Measures rather than Permian. A large majority of the genera and species are characteristic of the Carboniferous, and this Meek thinks sufficient to offset the fact that several genera previously considered typical of Permian[2] are present.

In the Upper Coal Measures of Arkansas out of 51 species, there are 25 in common with the doubtful strata of Nebraska, and 6 other species are common to the Nebraskan Permo-Carboniferous and the Lower Coal Measures of Arkansas, but have not yet been found in the Upper Coal Measures of the latter

[1] Page 33, op. cit.

[2] In the transactions of the Kansas Academy of Science, Vol. XIII., p. 38, Robert Hay announced that Professor H. S. Williams and Professor Tschernyschew had visited the Fort Riley section, and agree that it was undoubtedly Permian.

state. But of the genera mentioned by Meek as being considered not to antedate the Permian of Europe only two are found in the Arkansas strata, namely, *Synocladia*,[1] and *Lima*.

There is therefore not sufficient reason for classing the Poteau mountain beds with the Permian, but their fauna, as well as stratigraphic position place them very high in the Coal Measures, since they agree in fauna and position with the Mississippi valley Upper Coal Measures. These beds derive an additional interest from the fact that on Poteau mountain about one thousand feet of shales, in which no fossils were sought for, lie above the thin layer from which the entire collection was taken; thus the chances of finding true Permian beds in that region are very good.

RELATIONS TO THE TEXAS UPPER CARBONIFEROUS.

The only undoubted marine Permian in America has been described by Dr. C. A. White.[2] He finds the fauna of the upper Paleozoic beds of northern Texas, discovered by Professor W. F. Cummins, to be analogous to that of the *Fusulina* limestone of Sicily, the Artinsk stage of the Ural mountains, and the upper part of the *Productus* limestone of the Salt Range, India. These strata all show that peculiar commingling of ordinary Coal Measure fossils with ammonite genera, such as *Popanoceras*, *Medlicottia*, and *Waagenoceras*, which seems to be characteristic of open sea facies of the Permian.

None of the characteristic ammonite genera were found in the Arkansas region, but nearly all the fossils found in the Arkansas Coal Measures are also found in Texas. And in the Texas region nearly all the Permian species excepting the *Ammonites* were also found in the underlying Cisco division, which faunally and stratigraphically is the equivalent of the Upper Coal Measures of Arkansas.

Goniatites (*Gastrioceras*) *baylorensis* White is represented in

[1] WAAGEN has shown, in Pal. Indica, Salt Range Fossils, I. Productus Limestone Fossils, p. 802, that *Synocladia* is not found in America, the species described by Swallow as *Synocladia biserialis* being a *Septopora*.

[2] Bulletin 77, U. S. Geological Survey.

Arkansas by the closely related species *Goniatites globulosus* Meek and Worthen.

Orthoceras rushense McChesney, is found in both areas; the *Endolobus* is possibly the same in both, or closely related; *Euomphalus subquadratus* Meek and Worthen, is common to both; *Bellerophon crassus* Meek and Worthen, is found in both areas; *Pleurophorus* sp. is probably the same in both regions.

Nearly all the Upper Carboniferous species of Texas and Arkansas are also found in Illinois, Iowa, etc., in beds that have never been thought to be other than Coal Measures. We are therefore safe in concluding, that while some of the beds in western Arkansas are very high up in the Coal Measures, none that belong above them are as yet certainly known, and the Poteau mountain syncline, across the line in Indian Territory, is the only place where there is any likelihood of finding Permian deposits.

COMPARISON WITH FOREIGN UPPER CARBONIFEROUS.

The Lo-ping fauna.—The descriptions of the fossils of the Lo-ping district of China, by Professor E. Kayser,[1] throw great light on the relations of the American Carboniferous faunas to those of Asia. Near Lo-ping, in eastern China, are found in strata overlying the coal-beds, numerous marine fossils of Upper Coal Measure age. Kayser has described 55 species, 10 not specifically identified, 15 cosmopolitan species, and 11 forms that are typically American, and belong chiefly to the Upper Coal Measures.

The 15 cosmopolitan species are also nearly all found in the American Upper Coal Measures, so that of the entire Lo-ping fauna nearly all the species are either found in America, or they have their nearest relatives there. The two regions belong to the same zoölogical province, the Pacific Carboniferous sea.

Many of these species that are very common in America and Asia are unknown or rare in Europe, which fact would tend to prove a connection with Asia by water, and the separation of the European and the American Upper Coal Measure deposits by a land barrier.

[1] RICHTHOFEN: "China," Vol. IV.

The Carboniferous plants collected by Baron von Richthofen[1] numbered about 40 species and were nearly all identical with European Carboniferous plants. The natural inference is that in those times Asia was connected with Europe by land, and that the sea opened out to the east.

Professor J. S. Newberry[2] described a small collection of Carboniferous plants from China, and found nearly all of them to belong to well-known European species. This is in perfect agreement with the conclusions drawn above.

The Salt Range beds.—In the Salt Range, in northwest India, are found Upper Carboniferous deposits, some of which resemble those of Lo-ping, China; and the *Lower Productus* limestone of India is probably of about the same age as the beds of Lo-ping, and the western American Upper Coal Measures. These deposits and their fauna are described by Professor W. Waagen,[3] and in the volume on "Geological Results" he draws parallels between the faunas of the upper Paleozoic in different countries. Many of the American species that are found at Lo-ping are also found in the Salt Range *Lower Productus* limestone. This same type of Carboniferous is found in Sumatra, where it has been described by Ferd. Roemer,[4] and on Timor, where it was described by E. Beyrich.[5] This is the furthest southward that the Indian or northern type of Upper Carboniferous is known, and indeed the deposits of Sumatra and Timor begin to show already a greater affinity for the Australian or southern type of Carboniferous.

Waagen[6] divides the Carboniferous into two types, the northern or Asiatic, and the southern or Australo-African. The northern type is found in western Europe, Russia, the Himalayas, China, the Arctic regions and North America. The southern type is developed in South Africa and Australia, and extends into Penin-

[1] RICHTHOFEN: China, Vol. IV., Abhandlung 9, Dr. A. Schenk.

[2] American Journal of Science, Vol. 126, 1883, pp. 123 *et seq.*

[3] Paleontologia Indica. Salt Range Fossils.

[4] Paleontographica, Vol. 27, 1880.

[5] Abhandlungen der Berliner Akademie der Wissenschaften, 1864.

[6] Salt Range Fossils, Geological Results, p. 239.

sular India and Afghanistan. Brazil probably belongs to this type, but is to a certain extent transitional.

The Itaitúba fauna.—A comparison of the Upper Carboniferous fauna of Itaitúba, Brazil, as described in part by Professor O. A. Derby,[1] shows that of 27 species of *Brachiopoda*, 12 are identical with American forms, although most of these are cosmopolitan. The genus *Strophalosia* is common in these beds, and as Professor Derby[2] says, the species shows affinity with the Permian. Many of the new species described by Professor Derby are closely related to the European forms. Waagen[3] says that the beds of Itaitúba are of the same age as the *Middle Productus* limestone of India, that is of the Permo-Carboniferous transition beds. The Brazilian *Strophalosia* is closely related to Australian species, indicating a closer connection with the Australian or southern Carboniferous region than with the Pacific province. Hence we infer that the Brazilian deposits may after all belong to the Upper Coal Measures, and that the difference between them and the northern Upper Coal Measures may be geographic instead of geologic.

CLASSIFICATION AND AGE OF THE ARKANSAS COAL MEASURES.

Provisional classification.—For the sake of convenience, the Coal Measures of Arkansas have been provisionally classified by the Survey as Upper or Productive, and Lower or Barren Coal Measures. This division is not based on any paleontologic or stratigraphic break, but merely on the occurrence or non-occurrence of coal.

The divisions that are recognized in Pennsylvania could not be recognized in Arkansas, but the strata of the two regions are correlated as far as possible with the scanty data now at hand.

The Lower Coal Measures.—Of the age of the Lower Coal Measures we have only stratigraphic evidence, their position above the limestone of the Lower Carboniferous, and below the coal-bearing beds of the Lower Coal Measures being unmistakable.

[1] Bulletin Cornell University, Vol. I., No. 2.

[2] Op. cit., p. 60.

[3] Salt Range Fossils, "Geological Results," p. 207.

But their known fauna and flora have been too limited and too indecisive to enable us to correlate subdivisions with those of other Carboniferous areas, since collections have been made in but few places, and these chiefly in sandstones, where the preservation of fossils is usually unsatisfactory, and their determination uncertain.

But the Lower Coal Measures correspond in a general way to the Strawn and the Canyon divisions of Texas, the Pottsville conglomerate series, the Lower Productive Coal Measures, and part of the Lower Barren Coal Measures of Pennsylvania.

The Upper Coal Measures.—The Arkansas Upper Coal Measures correspond to the lower part of the Cisco of Texas, and belong just at the top of the true Carboniferous, and below the transitional Permo-Carboniferous or Artinsk stage, to which latter age the uppermost Cisco beds of Texas, with *Ammonites* (*Popanoceras*) *parkeri*[1] Heilprin belong. These may be the equivalents of the Poteau mountain marine beds.

The lower Permo-Carboniferous strata of Kansas and Nebraska are probably also to be correlated with the Artinsk[2] stage, although Waagen[3] classes the entire series with the ammonite-bearing beds of northern Texas, described by Dr. C. A. White in Bulletin 77 of the U. S. Geological Survey. The latter Texas beds, however, belong above the Artinsk stage, and in the true Permian, and are probably of the same age as the middle division of the *Middle Productus* limestone of the Salt Range.

Waagen, in "Salt Range Fossils, Geological Results," p. 238, gives a comparative table, showing the relationship of the upper Paleozoic strata all over the world. While the position assigned some of the American deposits does not agree with that accepted by most American geologists, still the table is useful for comparison, and it has been freely used in compiling the comparative table at the end of this paper.

[1] This horizon is at the top of the Cisco, and above the horizon of *Goniatites marianus*.

[2] KARPINSKY: "Ammoneen der Artinsk-Stufe," p. 92.

[3] Salt Range Fossils, Geological Results, p. 204.

The beds of Poteau mountain, Indian Territory, are probably of the age of the Lo-ping strata of China, while the yellow shales of Scott county, Arkansas, Township 1 N., Range 28 W., Section 4, southeast quarter of southeast quarter, are probably of the age of the Upper Carboniferous limestone of Moscow, and the west slope of the Ural Mountains, if we can judge by the occurrence of *Gastrioceras marianum* and *Pronorites* in them. This would make them older than the Poteau mountain shales, which is very likely the case.

Paleobotanic evidence.—Our knowledge of the paleobotany of the Coal Measures of Arkansas has been up to the present time very limited, depending almost entirely on the publications of Lesquereux, in the "Second Annual Report of a Geological Reconnaissance of the Middle and Southern Counties of Arkansas," 1860, and in the Second Geological Survey of Pennsylvania, Report of Progress, P, "Description of the Coal Flora of the Carboniferous Formation in Pennsylvania, and throughout the United States," 1884.

The joint monograph of H. L. Fairchild and David White, on the "Fossil Flora of the Coal Measures of Arkansas,"[1] throws much new light on the stratigraphic and regional distribution of species, and has been of material aid in correlating the Arkansas strata with those of other regions. They prove that all the Coal Measure plants[2] published from Arkansas belong to the horizon of the Upper or Productive Coal Measures.

The Van Buren plant bed is thought, from paleobotanic evidence, to belong above the horizon from which most of the coal of Arkansas is obtained, that of the Ouita coal, and this agrees with the evidence given by the stratigraphy and the marine fossils. The Van Buren plant bed occurs below the Poteau mountain marine beds, and above those in Sebastian county, Township 8 N., Range 32 W., Section 12; and these latter marine beds occur above the horizon of the Ouita coal.

[1] An unpublished report of the Geological Survey of Arkansas.

[2] The work of the Survey shows that the plants described by Lesquereux from Washington county as Sub-Conglomerate belong to the Lower Carboniferous.

The Poteau mountain marine beds are of about the same age as the Wyoming valley limestones[1] of the Upper Productive Coal Measures of Pennsylvania, and these belong below the Dunkard creek series of the Upper Barren Coal Measures. The Dunkard creek[2] beds have lately been proved by Professor I. C. White to be of the same age as the Permian of northern Texas, on the basis of plant remains that also occur towards the top of the Wichita series of Texas, in which marine Permian fossils[3] have already been found.

But the paleobotanic evidence aids in establishing the age of the Upper Coal Measures only; plants are not reported from any horizons of the Lower Coal Measures, although they are known from a few localities.

Owen[4] mentions *Stigmaria ficoides* as occurring at Patterson's mill, near Bee Rock, on Little Red river, White county. In August, 1892, a few plants were found by the Survey in the Bee Rock sandstone, near the base of the series and below most of the marine fossils, but none of these could be identified.

General D. McRae, of Searcy, informed the Survey that in Township 7 N., Range 7 W., Section 4, in White county, were found shales containing numerous *Lepidodendra* and ferns. These shales are above the Bee Rock sandstones.

In a well at Dr. Griffin's, Township 5 N., Range 10 W., Section 5, near El Paso, White county, specimens of *Lepidodendron* were collected by Dr. J. C. Branner, in micaceous flaggy sandstone, thought to be of the same age as the shales of Searcy. About fifty feet above the flaggy sandstone was found a thin bed of coal, and thirty feet higher was another coal bed with numerous ferns and *Calamites* in the overlying shales.

C. S. Prosser[5] mentions plants supposed to be of Lower

[1] Second Geol. Sur. of Pa., An. Rep., 1885, pp. 437–458, C. A. ASHBURNER and A. HEILPRIN, "Report on the Wyoming Valley Limestone Beds."

[2] Bul. Geol. Soc. America, Vol. III., p. 217.

[3] Dr. C. A. White, Bulletin 77, U. S. Geological Survey.

[4] Second Geol. Recon. Ark., Vol. I., p. 68.

[5] Ark. Geol. Survey, An. Rep., Vol. III., 1890, p. 423.

Carboniferous age, from Shinall mountain. In quarries in the sandstones of Big Rock, near the city of Little Rock, are found plant remains of indeterminable character. The stratigraphy of the Survey places both localities in the Lower Coal Measures, and probably above the fossiliferous sandstones of Bee Rock, on Little Red river.

THE PACIFIC CARBONIFEROUS SEA.

Revolution in Devonian time.—In Paleozoic times there have been many revolutions and alternations of continents and seas, and consequent readjustment of their inhabitants to new surroundings. One of the greatest of these was that which broke up a large zoölogical province, and put in direct connection regions that before were separated.

Dr. A. Ulrich[1] has shown that in lower and middle Devonian the faunas of Bolivia, Brazil, the Falkland Islands, and South Africa were very similar to those of North America, and that they were very different from the faunas of Europe and Asia. This state lasted until the end of the middle Devonian, when the revolution began. Professor H. S. Williams[2] has shown that with the beginning of the upper Devonian in America there came in a fauna, many species of which were not the direct descendants of those immediately preceding them. This new fauna was, however, closely related to forms known in Europe and Asia, but unlike those of the southern regions.

Professor Williams[3] afterwards elaborated this theory, and followed out closely the changes that were inaugurated towards the end of the Devonian. The culmination of these changes produced the Pacific Carboniferous sea.

The Carboniferous sea.—From chapter V., in Suess' "Antlitz der Erde," Vol. II., we get many valuable suggestions as to the outlines of the Pacific Carboniferous ocean. The Subcarbonifer-

[1] Beiträge zur Geologie und Paläontologie von Südamerika, I., "Paläozoische Versteinerungen aus Bolivien."

[2] Bull. Geol. Soc. America, Vol. I., "The Cuboides Zone and Its Fauna.

[3] Proc. Amer. Assoc. Adv. Sc., 1892, Section E, Address, "The Scope of Paleontology and Its Value to Geologists."

ous was the time of greatest transgression of sea over the present land areas, while the sea in which the *Fusulina* beds of Europe and America were formed was more circumscribed.

The Waverly group when traced towards the west gradually takes on the character of deep water formations; it is persistent through Nevada and California,[1] and is known, from unpublished investigations, to have a similar fauna in these two states. The Waverly probably persisted much longer in the west, than in the east, for in northern Missouri C. R. Keyes[2] has observed that in the midst of an undoubted Burlington fauna a well marked Kinderhook or Waverly fauna reappears. This he explains by Barrande's theory of colonies. It is probably an incursion of the inhabitants of a deeper western sea, where the Waverly had persisted longer, into the shallower eastern waters. The work of the Geological Survey of Arkansas shows that a similar phenomenon occurs in that state. The Fayetteville shale, which is probably of Keokuk age, contains a fauna that differs markedly from those of the limestones above and below it. An unpublished report by Professor Henry S. Williams shows the occurrence in the Fayetteville shale of several species that occur in a doubtful upper Devonian or lower Carboniferous black shale in the White Pine district, Nevada. Along with these Devonian or Waverly species occur others that belong much higher, as *Productus semireticulatus*, and *Goniatites* conf. *sphæricus*. Below the Fayetteville shale is the Boone chert, which at the base contains a decided Burlington fauna, and at the top probably belongs to the Keokuk. This has been observed in so many places that there is no possibility of mistake in the sequence of the strata.

We have therefore in Arkansas an incursion similar to that in Missouri, except that in Arkansas the incursion came considerably later. This is evidence that somewhere in the west the Waverly fauna persisted throughout the Burlington, and at least a part of the Keokuk. This is in accordance with the phenomenon described by Professor C. D. Walcott in Monograph VIII.,

[1] Zoe, Vol. III., p. 274; Proc. Calif. Acad. Sci., Oct. 17, 1892.

[2] American Journal of Science, December, 1892, p. 447.

U. S. Geological Survey, from the Eureka district, Nevada, where a Waverly fauna occurs 3000 feet above the base of the Carboniferous formation. The same thing has been observed by the writer in the Carboniferous of Shasta county, California.

The Lower Carboniferous limestones can be traced all through the west and the Mississippi Valley, to the base of the Appalachian Mountains, where they are replaced by conglomerates and other coarse sediments.

Upper Carboniferous in the West.—Of the Upper Carboniferous all that we know west of Indian Territory takes on a decidedly marine character, containing thick beds of limestones.

There are however some thin beds of coal in Texas, and some carbonaceous seams with a few land plants in New Mexico and Nevada. The coal in Texas was probably deposited near the southern shore line of the Carboniferous sea, and the carbonaceous seams in the far west probably belong to insular areas.

The fossils described from the Western Carboniferous are all marine, with the slight exception that Walcott[1] mentions a few specimens of pulmonate *Gasteropoda*, that were found along with brachiopods, corals, and land plants, evidently washed in from a distance, since no terrestrial Carboniferous deposits are known near the Eureka district.

The Pawhuski limestone.—In the eastern part of Indian Territory are found large deposits of coal in the Upper Coal Measures, but further west the same horizon is represented by marine limestone. In 1892 Mr. H. C. Hoover, of the Geological Survey of Arkansas, found at the government lime-kiln, three miles northwest of Pawhuski, Oklahoma Territory, Osage Agency, a bed of massive limestone about 100 feet thick, lying horizontally on heavily bedded sandstones. The limestone is fossiliferous, but the sandstones are not. The fossils collected were placed at my disposal, and on examination they proved to be:

Spirifer cameratus Morton.

Athyris subtilita Hall sp.

Productus semireticulatus Martin sp.

[1] Mon. VIII., U. S. Geol. Survey, p. 262.

Productus nebrascensis Owen.

Productus longispinus Sowerby.

Streptorhynchus crassus Meek and Hayden.

These are plainly of Upper Carboniferous age. The limestones cap the hills in that region, and spread over a great area, but fossils were collected at this place only.

Interchange of life between East and West.—The many beds of marine fossils in the Productive Coal Measures are simply transgressions from the western sea, and reach no further east than Pennsylvania and West Virginia. The Appalachian system was the western border of the ancient Atlantis[1] which separated the European from the Pacific waters, while the great Indo-Australian[2] continent bounded the Pacific ocean on the south. This ocean must have stretched from the American Coal Measures to eastern China, the Salt Range in India, the Ural Mountains on the borders of Russia, and into the Arctic regions, for we find related faunas in all these places. Whatever we have of western European Coal Measure species must have migrated from this direction, since on the east there was no direct communication with European waters. An example of this is *Productus giganteus*[3] Martin, which is common in Europe, and is found in the Lower Carboniferous of the McCloud river, Shasta county, but is not found east of that place, unless *P. latissimus* Sowerby, from Montana, west of the main chain of the Rocky Mountains, be an equivalent.

On the other hand, many species seem to be confined to, or characteristic of, this ocean; among them may be mentioned *Productus cora* d'Orbigny, which Waagen[4] says is not found in Europe, its nearest representative being *Productus riparius* Trautschold; it was however first described from South America.

Goniatites marianus Verneul is found in the Artinsk region of

[1] Suess: Antlitz der Erde, II., p. 17.

[2] Suess: Antlitz der Erde, II., p. 316.

[3] See Annual Report U. S. Geog. and Geol. Surv. Terr. 1883, Part I., p. 132, and Bull. Geog. and Geol. Surv. Terr. Vol. II., No. 4, p. 354.

[4] Pal. Indica, Salt Range Fossils, Brachiopoda, p. 677.

the Urals, probably in Sumatra, and in Arkansas. The genus *Pronorites*, while found in western Europe, is rare in it, and is much more common in the Pacific region. *Pronorites* is found in the Artinsk region and in Arkansas, while the ammonite genus *Medlicottia*, the direct descendant of *Pronorites*, is found in the Permo-Carboniferous strata of Sicily, the Urals, the Salt Range, and Texas.

It is impossible to suppose that the same genus and species originated at different localities, and since we have both ancestors and descendants in places so widely separated, we can only suppose that there was free interchange of life between those places at that time, or in other words an open sea, on the borders of which these fossiliferous deposits were laid down, and through which the cephalopods and other marine animals could migrate.

Replacement of Limestones by coal-bearing formations in western Europe.—On tracing the Upper Carboniferous deposits of the Ural region towards the west, we find the limestones thinning out, and the Coal Measures and Culm formations taking their places; we find also that the transgression of marine on terrestrial deposits takes place from the east, just the reverse of what is seen in America.

Land areas in the West.—It is not thought that the Pacific Carboniferous sea was an unbroken expanse of water in western America; on the contrary there are many evidences of large isolated land areas and archipelagos.

Dr. Joseph Le Conte[1] has argued that the Basin Range, during much of Paleozoic and Mesozoic time, was a continent, off the western shores of which the sediments that afterwards became the Sierra Nevada and Coast Range were laid down. Clarence King[2] thought that the great thickness of Paleozoic littoral deposits in the Great Basin region proved the existence of a large body of land further west; he thought that the eastern shore of this continent was in Nevada, and east of this stretched the Carboniferous sea, which covered all but the island chain of the Rocky moun-

[1] American Journal of Science, III., Vol. 16, p. 108.

[2] U. S. Geol. Explor. Fortieth Parallel, Vol. I., p. 534.

tain region. King[1] further concluded that the Carboniferous in California, west of the old shore line, indicated shallow bays that permitted the western extension of the upper Paleozoic deposits, while the bulk of them was stopped by the bold coast. There are evidences of land areas in the Rocky mountains, Wahsatch mountains, New Mexico, and Nevada, but from the facts now known it seems more probable that these were large islands or archipelagos, rather than continents.

THE PERMIAN PACIFIC OCEAN.

The outlines of the great western ocean can be traced in Permian times also, but with much more circumscribed limits. Open sea deposits of this age are known in Texas, in the Salt Range, on the west slope of the Urals, on the island of Sicily, and in scattering places in central Asia. In all these the genera are nearly the same, except that the *Arcestes* types are confined to the more southern regions. This similarity indicates plainly a connection of these deposits.

Suess[2] argues that the open sea Permian fauna wandered in from the south, and that the Mesozoic types of *Ammonites* were foreign to the northern regions.

Karpinsky,[3] on the contrary, holds that they were autochthonous, at least in the Ural region, since he could trace the descent of all the *Ammonites*, except the *Popanocerata* from *Goniatites* that were found in the underlying Carboniferous.

As has been already mentioned, the ammonite genus *Medlicottia* is not a foreigner on this side of the Permian Pacific ocean, because its ancestor, *Pronorites*, is found here too.

The Triassic Pacific ocean.—Our knowledge of the Triassic Pacific ocean is based on the work of Mojsisovics, "Arktische Triasfaunen."[4] We find that in this period the American part of the great western ocean has mostly become land, and only on

[1] Op. cit., p. 535.

[2] Antlitz der Erde, II., p. 316.

[3] Ammoneen der Artinsk-Stufe, p. 86.

[4] Mem. Acad. Imper. Sci. St. Petersbourg, Tome 33, No. 6.

the western border of America do we find marine Triassic beds, in Nevada, California, Idaho, and along the Coast region in scattering places from Alaska to Peru.

These deposits, with similar fauna, can be traced on the other side of the Pacific, from New Zealand, Timor, New Caledonia, to Japan and Siberia. This sea stretches out on one side over the Himalayas to the eastern Alps, forming what Neumayr[1] calls the "central mediterranean sea." On the south side the sea stretched up to Spitzbergen, but did not reach the Atlantic region. The Triassic was a continental period for the greater part of the present continents.[2]

After the Trias the outlines of the western ocean had changed entirely, and no resemblance to the original boundaries can be traced.

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[1] Denkschrift Wiener Akad., 1885, "Die Geographische Verbreitung der Juraformation."

[2] SUESS: Antlitz der Erde, II., p. 147.

CORRELATION TABLE OF THE COAL MEASURES OF ARKANSAS WITH THE PACIFIC CARBONIFEROUS PROVINCE

		Arkansas.	Indian Territory	Texas	Mississippi Valley	Pennsylvania	China and other parts of Asia	Russia and Ural Mts.	India	South America
Permian			Permo-Carboniferous	Wichita Series, with *Medlicottia*, *Popanoceras Waagenoceras*, etc.	Permo-Carboniferous of Kansas and Nebraska	Upper Barren Coal-Measures	Bokhara Cephalopod Beds	Kostroma Permian Artinsk Stage	Productus Limestones Speckled Sandstone Series	Itaitúba Beds
Coal-Measures or Pennsylvanian	Upper Coal-Measures	Poteau Mountain Marine Beds Van Buren Plant Beds Fort Smith Marine Beds Ouita Coal Horizon with Plants Boles, Scott County, Beds with *Goniatites marianus and Pronorites*	Productive Coal-Measures Pawhuski Limestone	Cisco	Upper Coal-Measures	Upp. Prod. Coal Meas. Wyoming Valley Limestones	Marine Beds of Lo-ping	North. Russ. NovaZembla	Spiti Limestones	Plant Beds
	Lower Coal-Measures	Morrillton Marine Beds Conway County Millstone Grit, with Marine Fossils Big Rock, Pulaski County, Plant Beds El Paso, White County, Plant Beds Searcy, Bee Rock, Marine Beds Searcy, Bee Rock, Plant Beds		Strawn and Canyon Divisions	Lower Coal-Measures	Lower Barren Coal-Meas. Lower Productive Coal-Meas. Pottsville Conglomerate	Productive Coal-Measures of China	Upper Carboniferous Limestone Middle Carboniferous Limestone	Muth Quartzites	
Lower Carboniferous or Mississippian		Lower Carboniferous Limestone	Lower Carboniferous Limestone	Bend Division	Lower Carboniferous Limestone	Mauch Chunk Series	Lower Carboniferous Limestone	Lower Carboniferous Limestone	Crinoidal Limestones	

PSEUDO-COLS.[1]

THE French term *col* is gradually coming into use to signify low passes or saddles on the watershed between drainage systems. Its use is very convenient in the discussion of reversed or diverted drainage, particularly that caused by the intrusion of glacial or igneous obstacles. It not infrequently happens that, when a glacier enters the lower part of a drainage basin, it ponds back the waters, and causes them to pass over such a col into a neighboring basin. Sometimes the valley becomes permanently filled with glacial wash and morainic debris to such an extent as to cause the diverted stream to retain its new course after the retreat of the ice. In such cases the stream, in subsequently deepening its valley, forms a trench across the col, which gradually takes on the form of an ordinary valley. In time the col is only represented by a constriction of the new valley and by certain residual features of the old topographic configuration. The floor of the trench across the col obviously assumes the slope of the new stream that caused it, and has its highest part on the up-stream side of the former col. As the trench is cut deeper and deeper, the highest point in the rock floor is gradually carried up stream. It may, in this way, be transferred some distance from the original col and may thus become entirely disassociated from its peculiar topographic relations. If, after this has been done, another glacial invasion takes place and the valley becomes again filled with glacial wash to some considerable height, the transferred summit of the rock floor is liable to lose its obvious connection with the old col and may perhaps seem to be associated with new and misleading topographic surroundings. If, in such a case, the valley debris is penetrated by wells at only a few points, and the investigator ascertains thereby only

[1] Presented in substance before the Geological Society of America at Boston, Dec. 31, 1893.

imperfectly the nature of the trench and the location of the rock summit in its buried floor, he is liable to mistake this obscured rock summit for a true col. It is, in fact, not a col at all in any proper sense. It never has been a watershed, and has never performed the functions or sustained the relations of a true col. As there is frequent occasion to refer to this phenomenon in the discussion of certain regions of reversed drainage along the border of the ancient glacial formations, I propose for it the distinctive name *pseudo-col*. The nature of the phenomenon has been more or less distinctly recognized by many geologists. The purpose of this note is merely to bring it forth into more definite recognition and to supply it with a convenient name which may be used in lieu of the cumbersome periphrastic phraseology now required.

T. C. CHAMBERLIN.

NOTE ON THE ENGLISH EQUIVALENT OF SCHUPPENSTRUKTUR.

IN a paper entitled "On the geological structure of the Housatonic valley lying east of Mt. Washington" (JOURNAL OF GEOLOGY, Vol. I. No. 8), I proposed the term (p. 791) *weather-board structure* as an equivalent of Suess's term *Schuppenstruktur* to describe a structure caused by a series of small compressed overfolds finding relief through dislocation, and resulting in the production of a parallel series of overlapping plates. Mr. Bernard Hobson, of Manchester, England, has suggested to me that the term *imbricate structure* would be better because of its Latin derivation and its use in botanical literature. The two terms are practically identical as regards the idea conveyed, and though the term first suggested would perhaps give a better mental picture to many minds, Mr. Hobson's term would be more readily understood abroad, and has the added advantage of being the English equivalent of Margerie's *structure imbrique*. I should therefore be glad to see *imbricate structure* adopted rather than the term which I at first suggested.

WILLIAM H. HOBBS.

GEOLOGICAL SURVEYS IN MISSOURI.

THE first geological survey of Missouri, having for its field of operations the whole state, exclusively, was provided for by an act of legislature just fifty-one years ago. A period of partial surveys by state and national governments had immediately preceded this, and a period of exploration and travel, and of primitive mining, was of still earlier date.

The explorations of Joliet, of La Salle, and of Hennepin, in the last quarter of the seventeenth century, had transformed the Mississippi valley from *terra incognita* to a promising field for adventure or profit, and, with the establishing of a settlement at the mouth of the Mississippi by Le Moyne d'Iberville in 1699, excursions up the river became frequent. In Le Sueur's expedition, in 1700, the existence of Missouri lead ores became known. This served, a few years later, as one of the incentives leading to the settling of the country by the Company of the West under the Crozat patent. From this time to the end of the eighteenth century the lead deposits were almost continuously worked, sometimes on a large scale, but no record of any careful investigation has come down to us from these early days.

With the beginning of the present century and the transfer of the territory to the United States, an era of somewhat closer observation seems to have been inaugurated. Among the earliest papers touching the geology of Missouri is Austin's "Descriptions of the Lead Mines in Upper Louisiana," written in 1804, covering a few pages of the American State Papers.[1] This is almost entirely descriptive of the lead mines of southeastern Missouri, and treats principally of their superficial features and conditions of development. During the next thirty years, a

[1] Public Lands, Vol. I., p. 188. Reprint Report Mo. Geol. Surv. 1873–74, p. 686.

number of similar short, descriptive reports appeared in these volumes.[1]

Between the years 1804 and 1807 the Lewis and Clarke[2] and the Pike[3] expeditions were conducted for the United States government. These expeditions added much to our knowledge of the geography[4] of the country traversed, but their geological results were meagre, and limited to a strip of country adjacent to the lines of travel.

The year 1815 is worthy of note as marking the beginning of the Land Office surveys in the state. These surveys continued until 1850, and supplied an admirable basis for future areal work in geology. Of interest in this connection is the fact that, during the first two or three decades of operations, the surveyors were required to report to the Land Office, along with their other field notes, the presence or absence of mineral on the land traversed. Drusy quartz, known as "mineral blossom," and other superficial phenomena of wide occurrence, were used as criteria, and, as these notes formed the basis for local classification, complaints soon became loud that so much land was being withdrawn from occupation on account of its being classed as "mineral land," that the settling of the country was seriously interfered with. This led eventually to the abandoning of the early, crude attempt at accomplishing some of the objects of a geological survey.

Schoolcraft's well known tours throughout the western country were made between the years 1816 and 1819, and the three volumes[5] of his observations contain much excellent statistical

[1] For specific references see Bull. No. 2, Geol. Surv. of Mo., 1890, Bibliography pp. 46 and 48.

[2] Travels to the Source of the Missouri River. By Capts. Lewis and Clarke, 1809 and 1814.

[3] Expeditions to the Sources of the Mississippi, etc. By Maj. Z. M. Pike, 1810 and 1811.

[4] Reference to the geographical results of this and other early explorations and surveys will be found in a paper by the writer entitled, "The Mapping of Missouri," Trans. Acad. Science of St. Louis, No. 8, Vol. VI., 1893.

[5] Views of the Lead Mines of Missouri, etc., 1819.

Journal of a Tour into the Interior of Missouri and Arkansas, etc., 1821.

Scenes and Adventures in the Semi-Alpine Region of the Ozark Mts., etc., 1853.

and descriptive matter relating to Missouri, and especially to the mines and topography.

The Long expedition of 1819,[1] similar in nature to the Lewis and Clarke and the Pike expeditions, was equally poor in geological results.

In the year 1821, Thomas Nuttal, the botanist, recorded certain observations on the "Geological Structure of the Valley of the Mississippi"[2] in which he alludes to the limestones of the valley and correlates them with Martin's *Petrifacta Derbiensis*. This, as Professor H. S. Williams has already pointed out,[3] is probably the first recognition of "Carboniferous rocks" in the region. Soon after this, in 1822, Dr. Edwin James called attention to the existence of a sandstone in the Ozark mountains of southeastern Missouri, with a clay slate, like the primitive slate of New England, intervening between it and the granite.[4] This was the first suggestion of the presence of Cambrian or Lower Silurian rocks in Missouri.

During the next ten and more years much attention was attracted to Missouri and other Mississippi valley states, through the extension of mining operations, especially in Iowa and Wisconsin. In volume 12 of the *American Journal of Science*, 1827, there are a number of references to mines and descriptions of minerals found.

During the years 1834 and 1835, G. W. Featherstonehaugh made his well known trip through Missouri and other western states.[5] In his reports he frequently refers to the limestones along the Mississippi as of Carboniferous age, and to the abundance of fossils in the exposures between St. Louis and Herculaneum, some of which he has found identical with European

[1] Account of an Expedition from Pittsburgh to the Rocky Mts., etc., 1823.

[2] Jour. Acad. Sci., Philadelphia, 1821, Vol. 2.

[3] Bull. No. 80, U. S. Geol. Surv., pp. 25 and 137.

[4] Jour. Acad. Sci., Philadelphia, 1822, Vol. 2.
Also: C. D. Walcott, Bull. 81, U. S. Geol. Surv.

[5] Geol. Report of the Elevated Country between the Missouri and Red Rivers, 1835.
Reconnaissance to the Green Bay and the Wisconsin Territory, 1836.

forms. From this and other statements it is plain that he did not discriminate between the different limestone formations which we now recognize in the Mississippi valley. He made a special examination of southeastern Missouri, and expresses the conclusion that the disseminated lead ore of Mine la Motte must necessarily have been deposited at the same time as the limestone; also that the veins of this country undoubtedly descend very deep towards the central part of the earth; and, finally, that the ore in these veins was "projected from below," the lateral veins from a main lode being compared to the branches of trap dikes, while the red clay is paralleled by the red mud accompanying volcanic eruptions in Sicily. The iron ores of Missouri, he also states, are of direct subterranean origin and fill veins or fissures produced by dislocation.

Though such ideas seem extravagant to us now, they were discussed and believed by scientific men of the day. Thus, in the proceedings of the fifth session of the American Association of Geologists and Naturalists, after a statement of Professor J. Locke's, that the Trenton age of the rocks containing lead ores of the upper Mississippi had been determined, Dr. Houghton replied that he did not think the ores were confined to any special limestone, but that they had been sublimed and segregated through the heat of intrusive trap. R. E. Rogers expressed himself in support of a similar explanation. In answer to this Dr. H. King sagaciously remarked that no volcanic or igneous action had taken place in Missouri or elsewhere in this lead region, and thus could not have influenced the segregation of the lead; that the subjacent rocks were not traversed by dikes, and that the lead ore was imbedded in the rock, like masses of chert.[1] Again Mr. J. T. Hodge, in 1842, in a long article on the Missouri and Wisconsin-Iowa mining regions, after describing copper deposits of Missouri, concludes that the copper ore had apparently been projected from below, either melted by sublimation or by slower electrical causes.[2]

[1] See Am. Jour. Sci., Series I., Vol. 47, 1844, p. 106.

[2] Am. Jour. Sci., Series I., Vol. 43, 1842, p. 69.

The year 1840 brings us to the date of publication of Owen's report on the Mineral Lands of the United States in portions of Iowa, Wisconsin and Missouri,[1] following closely upon his report as state geologist of Indiana upon work of 1838 and 1839. In 1844, a second and revised edition of his Mineral Lands report was issued, and, in 1852, his final report on Wisconsin, Iowa, and Minnesota appeared. These reports supplied the guiding lines along which later stratigraphic work in the Mississippi valley was done. Without attempting here to present the history of this work,[2] its bearing upon the future work in Missouri calls for brief mention. In the Indiana reports Owen makes a separation of the rocks, in harmony with the English classification, into: (1) Bituminous Coal formation; (2) Mountain limestone; (3) Grauwacke; (4) Crystalline and inferior stratified rocks. In the succeeding reports, as the results of wider observation and more thorough study, the classification was changed and differentiated until, in the final report, we find a classification which, not only in its general features, but in many of its details, is still adhered to in Missouri. The map accompanying this report attempts a representation of the areal geology of the northern half of the state. On this map the western margin, as far east as Wellington, is colored as belonging to the Upper Series of the Carboniferous limestone; along the Mississippi river a similar belt of both the Upper and Lower Series is represented; while, along the Missouri river, from above Jefferson City to Tower Rock, is an area of Lower Magnesian limestone. Between these a broad stretch of Coal Measures is shown.

The explorations and surveys thus far referred to were the results of private enterprise or were made under the auspices of the national government. The earliest record we have of action on the part of the state is in the message of Governor Lilburn W. Boggs in 1833. He there recommends an appropriation for

[1] House Exec. Doc., No. 239, 26th Congress, 1st Session.

[2] For summary concerning the Devonian and Carboniferous, see H. S. Williams, Bull. 80, U. S. Geol. Surv., p. 137 *et seq.*

a geological survey as an adjunct to a general system of internal improvement. Shortly after this a Board of Internal Improvements was formed, and, among other works, surveys of the Meramec, of the Salt, of the North Grande and of the Osage rivers were started. In connection with this, a geological examination by Dr. Henry King was made along the Osage river, and a report of twenty pages was published in 1840.[1]

Much of this report is devoted to the topography and soils, and to a description of occurrences of ore. Dr. King assigns all of the rocks of the region to the Carboniferous formation and separates them into two series: (1) A lower Galeniferous or Lead series; (2) an upper Coal series. By the former he plainly means the magnesian limestones and associated sandstones, though the section given is very imperfect; in the latter he includes the Encrinital or Lower Carboniferous limestones as well as the overlying coal beds, sandstones, and shales. The change between the two series is so marked, however, that he expresses the feeling that an entire separation of the two is almost justifiable. The lead ores of the region he assigns to the uppermost member of the lower series; the surface float ore, or "patch mineral," as he calls it, he determines correctly to be residuary from the decay of the limestone.

After this, further investigations by the state seem to have fallen into neglect for several years; but, by 1846, the subject again excited public attention and the question of a geological survey called forth a number of memorials from conventions, and of papers prepared by scientific associations, and was further recommended in the messages of several governors. Finally, by an act approved February 24, 1853, the First geological survey of Missouri was authorized.[2] The act controlling the First geological survey provided for the appointing by the governor

[1] Senate Journal, Appendix, 1st Session, 11th Gen. Assembly, 1840, pp. 506–525.

[2] Additional information beyond what is given in the following pages, relating especially to the laws governing the various state surveys, their organization, and plans of work, will be found in an historical sketch of Missouri Geological Surveys, forming part of the writer's Biennial Report to the 36th General Assembly, House Journal, 1891.

of a state geologist, who, in turn, was allowed the appointing of not more than four assistants, who were to be skilful chemists, and of such other subordinate assistants as he might deem necessary. The work of the survey was to include stratigraphic and structural geology and special studies of economic geology. Annual reports were required, and a final report, or a complete memoir on the geology of the state, was to be prepared on the completion of the survey. Specimens in triplicate were to be collected and forwarded to the Secretary of State; one set for a cabinet in the state capitol, another for the state university, and the last for the city of St. Louis. Ten thousand dollars annually for a term of two years were appropriated.

Pursuant to the instructions of this law, Professor G. C. Swallow was appointed state geologist by the governor in 1853. Professor Swallow came directly from Maine, where he had been engaged in teaching. The survey continued in active operation until, June 1861, under the direction of Professor Swallow. The controlling plan of the work as laid down by him, in the letter of transmittal accompanying his second annual report, was to prepare: "First, an outline of the geology of the state; second, a general view of the mineral wealth of the mining districts; third, an exposition of the agricultural and manufacturing resources of the state; fourth, reports in detail upon as many counties as possible."

Five reports were published by this survey, but the second, of 447 pages (with which is printed the first, of but four pages) is the only one which embodies the results of field work, and this is the one generally known as the Swallow report. The others are very brief reports of administration and progress. Part I of this Second Annual Report contains chapters by Professor Swallow on the general geology of the state and two county reports; Part II contains a chapter by Dr. Litton on the lead mines of southeastern Missouri, and three county reports by Meek and Shumard, as well as several general cross sections and a short paper on paleontology.

After the issue of this report the survey continued in active

operation until 1861, during which time its labors seemed to have been centered upon systematic county work, leading to the production of special county maps and reports. A table contained in the fifth report of progress shows that, up to the end of 1860, field work had been completed in eighty counties, and of these, reports had been made upon thirty-three; in a considerable number of other counties more or less work had been done. Five of these reports were contained in the Second Annual, and twenty more constitute a report issued in 1873; others were probably used in the preparation of the county descriptions of the other reports of 1873 to 1874. In addition to this work, during the period of the first survey, Professor Swallow made an official report of ninety-three pages on the Southwest Branch of the Pacific Railway.

Reviewing, briefly, this work of the First geological survey, we must recognize as remarkable and excellent the classification of the rocks which are evolved, as well as the general accuracy with which the distribution of the formations was defined, especially when the short time is considered; avowedly under the control of Hall's New York classification and nomenclature, published in 1843, though undoubtedly assisted, yet not misled by Owen's results, Swallow and his assistants established a table of formations, and outlined a geographical map of the state which remains to this day unchanged in its larger features.

From 1860 to 1870, geological work was nearly at a standstill in the state. During this period, however, Professor Swallow, as professor of geology at the state university, and various of his assistants in different capacities, extended their observations in the state, and published the results in scientific journals or in the proceedings of scientific societies.[1]

In March, 1870, an act was passed authorizing the Second geological survey. The provisions of this act were in the main similar to those of the first, with the exception that the Bureau was placed under the control of a board of managers of nine

[1] For a Bibliography of the Geology of Missouri, see Bull. No. 2, Mo. Geol. Survey, 1890.

members. The state geologist was allowed to appoint one assistant state geologist, who was required to be a chemist, at an annual salary of $2,000; also other subordinate assistants at not more than $1.50 per day. Provision for the appointment by the Board of a state assayer was also made. For the "general expenses" of the bureau the sum of $7,500 was allowed annually Under this law Albert D. Hager, previously of the Vermont survey, was appointed state geologist. The law was amended in March, 1871. The number of the members of the Board was reduced to four, and the allowance for the annual expenses raised to $10,000. Mr. Hager held this position until August, 1871, and published one report of progress, twenty-one pages in length, in which he briefly notices the chief building stones and minerals of the state. After Mr. Hager's resignation, Dr. J. C. Norwood was in temporary charge. In November, 1871, Mr. Raphael Pumpelly was appointed state geologist. He resigned from the position in May, 1873.

Up to the time of Mr. Pumpelly's appointment, very little had been made public of the results of the surveys, and the changes of management must necessarily have retarded and weakened the work. Notwithstanding this, however, Governor B. Gratz Brown, in his message of December, 1871, commends the survey warmly to the Legislature, and, as a result, the law was amended in the following March, and the sum of $20,000 was appropriated annually for the salaries and expenses of the Bureau.

Two classes of work were provided for in the Pumpelly survey, *i. e.*, (1) the study of the stratigraphy of the state; (2) the study of the mineral deposits. The stratigraphic work was divided into five departments covering different sections of the state; that of economic geology was divided into three, including a department of iron ores and metallurgy, a department of ores other than iron, and a department of fuels and materials of construction other than iron and wood. Under the Pumpelly management two reports were issued in 1873. The first was an octavo of 323 pages, already referred to as containing twenty

county reports, prepared during the Swallow survey.[1] The second volume was a large octavo of 655 pages[2] transmitted in April, 1873. Part I consists, first, of a chapter on the geology of Pilot Knob and vicinity by Mr. Pumpelly; the second chapter embodies analyses of ores, fuels and pig irons; chapters III to IV, inclusive, constitute a partial report on the iron ores of Missouri by Dr. Adolph Schmidt. Part II consists of fifteen chapters and three appendices; of these, chapters I to VI contain general information relating to the coal fields of the state by Prof. G. C. Broadhead; chapters VII to VIII are on the geology of Lincoln county by Prof. W. B. Potter; chapters IX to XV consist of reports on seven counties by G. C. Broadhead; appendices A, B and C relate to building stones and contain a list of Coal Measure fossils.

After Mr. Pumpelly's resignation, Prof. G. C. Broadhead was appointed state geologist and assumed charge in July, 1873. During this administration the examinations of the iron ores and of the lead and zinc deposits were continued, and surveys for a number of county reports were made. One volume was issued by the Broadhead survey.[3] This is a large octavo of over 790 pages transmitted in August, 1874. Chapters I to VI, inclusive, are upon general topics relating to the history of exploration and the general geology of the state by Professor Broadhead; chapters VI to XXI, inclusive, consist of reports on fifteen counties; chapters XXII to XXXII, inclusive, and XXXIV, describe the lead and zinc deposits of the state from work done by Dr. Schmidt and Mr. A. Leonhard; chapters XXXIII and XXXV relate to the iron ores of southeastern

[1] Reports on the Geological Survey of the State of Missouri, 1855–1871, by G. C. Broadhead, F. B. Meek and B. F. Shumard, Jefferson City, 1873, pp. 324 and iv.

[2] Geological Survey of Missouri, Raphael Pumpelly, Director. Preliminary Report on the Iron Ores and Coal Fields, from the field work of 1872, with 190 illustrations in the text and an atlas. New York: Julius Bien, 1873. P. xvi., 214 and 441.

[3] Report of the Geological Survey of Missouri, including field work of 1873–74, with 91 illustrations and an atlas. Garland C. Broadhead, State Geologist, Jefferson City, 1874. Pp. 734, L. 4, 50.

Missouri. Appendices A, B, C and D contain much statistical and other matter of subordinate interest.

The survey was discontinued after the year 1874, and most of its working material was transferred to the state School of Mines at Rolla, of which the president, Dr. Charles P. Williams, was made acting state geologist, with a nominal appropriation. Little field work seems to have been carried on under Dr. Williams, and, after the year 1876, no further support was extended to the work by the state. One report was prepared by Dr. Williams, which consists of a small octavo of 117 pages. It contains a chapter on the "Mineralogy and General Metallurgy of Lead," one on the "Zinc Industry of Missouri," one on the "Iron Industry," and one on "Shannon County"; in the appendices are given a few statistics of lead and zinc, and a "Note on the Occurrence of Gold in Northwestern Missouri."

Reviewing the results of the Second geological survey, its contribution to our knowledge of the geology of the state consisted principally: (1) of Pumpelly's observations, too soon interrupted, upon the crystalline rocks, whose work threw much new light upon their nature and relations, though the report has left us in some doubt as to whether he considered the whole mass of the porphyries metamorphosed clastics, or whether he meant this to apply only to the Pilot Knob beds; (2) of Broadhead's detailed stratigraphic results in the Coal Measures which placed on record many new and valuable sections, added much concerning their correlation, and demonstrated the thickness of this formation to be much greater than had been formerly believed; (3) of Schmidt's report on the iron ores and lead and zinc deposits, especially strong in its treatment of the mineralogy, but deficient in its interpretations of structure, and lacking in suggestions as to origin and processes. The classification of the clastic rocks remained substantially the same as tabulated by Swallow and Shumard, the principal changes displayed in the chart opposite page 18 of the report of 1873–74 being in the subdivisions of the Lower Carboniferous; in the transference of the Chouteau, Vermicular and Lithographic stages to this series; and

in the assignment of the Third Magnesian limestone and all below it to the Potsdam period.

Summarizing the products of both the First and Second surveys, we find that there were published six volumes, varying in length from ninety-three to over 700 pages, and four pamphlets, aggregating about fifty pages. The appropriations for these two geological surveys, as given by Broadhead.[1] are as follows:

	APPROPRIATIONS.	EXPENDITURES FOR PRINTING.
From 1853 to 1862 - - - -	$105,000	$5,000
1870 and 1871 - - - -	12,500	
Under acts of 1872, 1873 and 1874	60,000	19,320
In 1876 and 1877, and by School of Mines - - - - -	5,000	1,500
Printing, 1873 - - - - -	12,000	
Printing, 1876 - - - -	1,500	
Total - - - - -	$196,000	$25,820
Unexpended appropriations -	19,814[2]	
Total expended - -		$176,185
Balance for salaries and current expenses - - - -		150,365

After the stoppage of the apology for a geological survey, for which provision was made under Professor Williams' control, no public geological work was conducted until the year 1884, when topographic work was begun in the state by the United States geological survey. This was continued until July, 1889, up to which time about one-third of the state was mapped on sheets of a scale of two miles to the inch, and with contour intervals of fifty feet. In addition Mr. W J McGee was detailed in 1887, by the national survey, to make a brief study of the geology of a portion of Macon county, the results of

[1] Missouri Geological Surveys. Historical Memoir. Trans. Acad. Sci. of St. Louis. Vol. IV. Pp. 611–614.

[2] We are informed by Professor Broadhead that the larger part of this unexpended appropriation belonged to the period of the Swallow Survey, though part of it also reverted during the Hager administration of 1870 to 1871.

which are published in Vol. V. of the Transactions of the St. Louis Academy of Science.

In May, 1889, the act authorizing the present, or Third geological survey, was approved. It was evidently framed upon the laws of the preceding surveys, though it differed from them in detail. The most noticeable differences are the absence of a requirement to collect specimens in triplicate, and the absence of a clause requiring county maps and reports to be prepared. The state geologist is, however, directed to have complete and detailed maps and reports of counties or districts prepared. The appropriation for the two years, 1889 and 1890, was $20,000; that for 1891 and 1892 was $40,000; out of this all salaries and expenses were to be paid, including cost of publication. For the years 1893 and 1894, $20,000 have been appropriated, though the paper for publications is furnished in addition.

The writer was elected state geologist in August, 1889, and entered upon the discharge of his duties the end of September following. The plan of work adopted for this survey was: (1) to prepare a series of monographic reports upon separate subjects, which may be called Subject reports, applying to the whole state; those subjects of direct economic importance to receive first consideration; (2) to prepare successively a series of detailed maps of different portions of the state, and to accompany these with special reports containing much descriptive detail, which we may call Area or Sheet reports.

The subjects of work so far undertaken have been: the lead and zinc deposits; the coals and the Coal Measures; the clays; the iron ores; the mineral waters; the building stones; the crystalline rocks; the Quaternary, or, more exactly, the glacial geology; the paleontology; the hypsometry; general geologic mapping. Work has advanced on all of these subjects to varying extents. The study of the lead and zinc deposits was begun in coöperation with the national geological survey, but has been carried to completion by the state survey, and the report is now nearly finished. A Preliminary Report of 226

pages on the Coals of the state, by the writer, has been issued, but a great bulk of additional information has been gathered for a final report. The field work for the report on Clays was finished last year, and the report, by Prof. H. A. Wheeler, is now well advanced. A report on the Iron Ores of 391 pages, by Frank L. Nason, was published in 1892, together with one of 280 pages on the Mineral Waters, by Paul Schweitzer. The building stones were studied first by G. E. Ladd and later by Hiram Philips, but the field work is not yet completed, and had to be suspended this year. The crystalline rocks were studied by Erasmus Haworth and the report is written, but is withheld from publication for lack of funds. Field work for a preliminary report on the glacial geology, by J. E. Todd, was completed last year, and the report will soon be ready for transmission. An exhaustive review of the paleontology of the state by Charles R. Keyes is ready for publication. All available data relating to the hypsometry of the state have been collected and tabulated, and a few months additional work will put them in shape for publication. Along with the prosecution of work on these general subjects, many additional facts for more exact and detailed geological mapping have been collected; but in addition to this, mapping of the formations has been specially done over certain important areas of the southwestern and northeastern portions of the state.

For the Area or Sheet reports, fifteen sheets have been prepared, distributed over the central portion of the state along the margin of the Coal Measures, over the southwestern lead and zinc district, and over the southeastern lead district and Archean area. These sheets are on a scale of one mile to the inch with a twenty-foot contour interval, and cover each a quadrilateral of fifteen minutes of latitude and longitude. They include, in addition to the topography and general geology, much detail of special economic importance. Three of these sheets have been engraved, and the accompanying reports printed. The others are about ready for the engraver, and the reports are partly prepared.

Summarizing the official publications of the Third survey to date they are as follows:

Reports published:

Vol. I. A Preliminary Report on Coal, 8vo, 226 pages; Vol. II. Report on Iron Ores, 8vo, 391 pages; Vol. III. Report on Mineral Waters, 8vo, 280 pages; Five Bulletins, including a Bibliography of the Geology of Missouri, and articles on the coals, building stones and clays, mineral waters, crystalline rocks, and paleontology, aggregating 470 octavo pages. Also two administrative Biennial Reports aggregating 90 pages.

Three sheets and accompanying reports as follows: No. I. Higginsville Sheet and large folio report, 18 pages; No. II. Bevier Sheet and octavo report, 90 pages; No. III. Iron Mountain Sheet and octavo report, 96 pages.

Reports completed but not published:

Report on Paleontology, 400 8vo pages (estimated); Report on the Crystalline Rocks, 300 pages (estimated).

Reports nearly completed:

Report on Lead and Zinc Deposits, 500 8vo pages (estimated); Report on Clays, 400 8vo pages (estimated); Report on Quaternary Geology, 150 8vo pages (estimated); Report on Hypsometry, 150 8vo pages (estimated).

Reports only partly prepared:

Final Report on the Coal Measures; reports on twelve sheets of detailed mapping.

ARTHUR WINSLOW.

EDITORIALS.

THE doctrine of isostasy has been tentatively accepted by many working geologists. It finds application in various departments of geology, but nowhere more conspicuously than in glaciology. Without passing judgment on the doctrine, and without attempting to restrict the field of its application, attention is called to a misapprehension to which it has given rise. This misapprehension is widespread in the popular mind, and has even found a foothold among those who have given attention to glacial geology.

Among the hypotheses which have gained more or less currency in explanation of the Pleistocene glacial climate, is that of northward elevation. Whatever may be thought of this hypothesis from *a priori* considerations, or whatever may be thought of the evidence which is adduced in support of it, it has come to have an appendix which we believe to be false. This appendix seems not to have accompanied the hypothesis at the outset, and some of the advocates of the hypothesis do not appear to have given their sanction to the appendix, though their names are sometimes connected with it.

The hypothesis is, that northward elevation lowered the temperature of the region affected to such an extent as to occasion the accumulation of the Pleistocene ice-sheet. The appendix is, that the elevated area sank under the weight of ice for which it was responsible, until, as a result of the sinking thus effected, the climate was so far ameliorated as to bring about the melting of the ice-sheet and the end of the glacial period. The appendix is sometimes stated in milder form, the depression resulting from the weight of the ice being looked upon as only one of the causes which brought about the dissolution of the ice-sheet. This view, both in its wider and in its more restricted sense, we

believe to be without foundation. Its fallacy appears when the quantitative elements of the problem are considered.

Let it be assumed that northward elevation was the cause of the cold climate which made the development of the Pleistocene ice-sheet possible. Let it be assumed further (and this is the assumption most favorable to the doctrine here opposed), that the elevated region was in isostatic equilibrium at the time the ice began to accumulate. Let it be assumed also, that the average specific gravity of the mass of snow and ice of the ice-sheet was one-third that of the rocks of the earth's crust. On the doctrine of isostasy, depression should have accompanied the accumulation of snow and ice. When the central part of the snow-field had a depth of 300 feet, the maximum depression which it could have caused, under the assumed conditions, was 100 feet. At the minimum, therefore, the surface of the central part of the ice-field must have been 200 feet higher than the surface of the land before the ice-field formed. Nearer the margins of the ice-field, where the ice was thinner, both the depression of the land surface and the accompanying elevation of the snow surface would have been less; but each point of the surface of the snow-field must have been higher than the corresponding point of the surface of the land at the time the ice began to accumulate, and the temperature at all points must have been correspondingly reduced. Instead of being ameliorated by the depression of the land surface, the very conditions which brought about this depression were causing the climate to become progressively more severe. When the ice had attained a thickness of 3,000 feet, it might have occasioned a maximum depression of the subjacent land surface to the extent of 1,000 feet, and therefore a minimum elevation of the ice surface at the same point, to the extent of 2,000 feet. While, as before, both the depression of the subjacent land surface and the correlative elevation of the surface of the ice-sheet would have been less near the margins of the snow-field than at its center, it still remains true that each point of the entire surface of the ice must have been higher than the corresponding point of the surface of the land at

the time the ice began to accumulate, and higher than the corresponding point of the surface of the ice at every earlier stage. When 3,000 feet of ice had accumulated, and when this body of ice had caused its full measure of depression, the temperature over it must have been reduced at each point by an amount corresponding to the actual increase of elevation of the snow surface over the pre-existent land surface at that point. The force of the point here made is in no way lessened if the depression caused by the accumulation of the ice lags behind the accumulation itself. In so far as the sinking lags behind the loading, the temperature of the surface is reduced beyond the limits indicated. The principles here referred to will neither be reversed in their operation, nor rendered nugatory, by further accumulation of ice. So long as the ice thickens, it will remain true at all times that each point of the surface of the ice-field must be higher than the corresponding point at any earlier stage in the process of accumulation, isostasy alone being considered. The elevation of the ice surface (and this is the surface which determines the climate), will overbalance any depression of the land surface which the ice can cause by the disturbance of isostatic equilibrium. There is, therefore, not only no tendency to the amelioration of climate as the result of excessive snow accumulation, but there is a constant reduction of temperature. Whatever may have caused the dissolution of the Pleistocene ice-sheet, it was not the amelioration of climate resulting from the depression caused by the weight of the ice itself, under conditions of isostasy. R. D. S.

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WITH this number, THE JOURNAL OF GEOLOGY begins the publication of a series of articles on the geological surveys of the various states of the Union. These articles will be prepared, so far as practicable, by the official geologists of the several states. Their purpose is to publish to the geological world the present condition of geological work in the various regions with which they deal. They will indicate what has been done, and by whom. They will make known the various plans on which survey work has been prosecuted in the several states. They will

state the problems which still remain to be solved, and something of their relative importance. They will bring out the scientific and economic advantages which have resulted, directly or indirectly, from the surveys already executed. They will indicate the general scope of the more important publications, both cartographic and textual, which have appeared, and while they are not intended to be bibliographic primarily, they will contain references to the more important publications and to such bibliographies as may have been compiled. In some cases, at least, they will give the cost of the work which has been accomplished. The plan also involves a series of articles on the surveys in foreign countries. It is hoped and believed that these papers will be of much value. A considerable period of time will necessarily elapse before the series is completed, but in the end it is believed that it will constitute a valuable compendium of geological work throughout the world.

R. D. S.

Reviews.

The Economic Geology of the United States. By R. S. Tarr, Assistant Professor of Geology at Cornell University. 8vo, 509 pp. Macmillan & Co., 1894.

This volume discusses the ore deposits and other minerals and rocks of commercial value found in the United States, as well as a few of the foreign deposits of a similar nature. The book is divided into three parts. Part I. treats of the general mineralogical, geological and technical subjects more or less directly related to the various mining industries. It gives, first, a chapter on "Common Rock and Vein-Forming Minerals," followed by chapters on the "Rocks of the Earth's Crust," the "Physical Geography and Geology of the United States," the "Origin of Ore Deposits," and "Mining Terms and Methods." Part II. treats of "Metalliferous Deposits," including the ores and deposits of the useful metals. Part III. treats of the "Non-metallic Mineral Products," such as coal, petroleum, fertilizers, building stones, etc. In addition, the volume also contains a short appendix on the "Literature of Economic Geology." The object of this volume, as stated by the author in the preface, is to supply the pressing need of a text-book to accompany a series of lectures given by him to a class of students in economic geology at Cornell University.

The book is beautifully printed and neatly bound. The illustrations are well reproduced, and, in fact, all of the publishers' work on the book is very good and reflects credit on Macmillan & Co. The book is written in good language, and the general scheme in the arrangement of the subject matter is logical, but the text is deficient and contains many erroneous statements. The chapters on the "Rocks of the Earth's Crust" and on the "Physical Geography and Geology of the United States," give a fair general idea of those subjects, although even here there are a number of inaccuracies. The chapter on "Common Rock and Vein-Forming Minerals" and parts II. and III. of the book, treating of "Metalliferous Deposits" and "Non-Metallic Mineral Products," however, relate more especially to economic geol-

ogy, and are the essential features of the volume. They, therefore, deserve consideration in some detail.

The most important feature of a book of this kind is the discussion of ore deposits, yet at the outset a faulty definition of the term "ore" is given. The author says, on page 15, "an ore may be defined as a mineral with a metallic base." Unless further qualified, this definition is, to say the least, vague, for though all ores have metallic bases, there are a number of important minerals with metallic bases which are not ores. Thus, oxide of iron, sulphide of lead, sulphide of copper and other materials have metallic bases, and under proper conditions are ores; but gypsum, calcite, baryta, mica, and many other minerals have metallic bases and are not ores. Moreover, though many ores are minerals, many others are not minerals at all, but are common rocks having some special metallic constituent as their only unusual feature. Thus the ore of the Calumet and Hecla copper mines is a cupriferous conglomerate, the Mansfeld copper deposits of Germany are cupriferous shales, and many other similar instances might be mentioned. The author adds that, "properly speaking, the metallic constituent should be a predominant constituent." Though in some ores the metallic constituent is a predominant one, yet in some of the most important ores the metal forms only a small, and often an insignificant, constitutent. In most gold ores the metallic constituent forms but a fraction of one per cent. of the ore, and in most silver ores the silver forms but a slightly larger amount. In copper deposits, the copper rarely forms a large percentage of the ore, and in many other cases the metallic constituent is entirely subordinate.

The author states that "the miner considers an ore to be a mineral with a metallic base, occurring in sufficient abundance to be economically valuable; but from the scientific standpoint, a grain of magnetite in a granite rock is as much an ore as a bed of this mineral." The term ore is essentially a technical mining term, and has no scientific significance whatever. When a metal can be profitably extracted from a certain material, that material becomes an ore; but other materials may contain just as much of the same metal, and yet, on account of their mineralogical or other features, they may not be commercially profitable sources of the metal, and then they are not ores. Whether a material is an ore or not, is dependent on commercial conditions, which may vary from time to time; and this very fact prevents the term from having a scientific meaning.

On page 16 the author says that "the group of silicates is extremely large, including many of the important rock-forming minerals, but as ores they are of little importance." He has evidently overlooked the fact that calamine, a hydrous silicate of zinc, is an important ore, and that garnierite, a hydrous silicate of nickel and magnesia, is the source of a large part of the nickel of commerce. The latter is the ore mined at New Caledonia, off the coast of Australia, one of the two largest nickel producing regions in the world. It also occurs in the United States. The author again overlooks this silicate when, on page 26, in enumerating the ores of nickel, he says, "nickel is obtainen from the two sulphides, millerite, niccoliferous pyrrhotite, and the arsenide niccolite." In other deposits also silicates form a minor but an important part of the ore, as in the case of chrysocolla in the copper ores of Arizona.

On page 18 the author states that, "Sometimes, though not commonly, gold occurs in iron pyrites in invisible grains." It is almost unnecessary to say that one of the most common modes of occurrence of gold is in intimate association with iron pyrites, so that this statement is extremely misleading.

On page 20 the author says: "Gold occurs in the earth in only two mineralogical forms, so far as known, one in association with tellurium, the other native, the latter being its typical occurrence and the one from which the gold in use is obtained." It is true that native gold is the source of most of the gold in use, but the telluride ores, far from producing no commercial gold, are in many mines an important source of that metal. At Cripple Creek, in Colorado, the tellurides form an important part of many of the ores, and this district produced between $2,500,000 and $3,000,000 in gold in 1893. In Boulder county, Colorado, tellurides are also of importance, and have been so for many years past, while tellurides frequently occur in still other places.

On page 22 the author, in speaking of copper, says: "Its most common occurrence, however, is as the sulphide, *chalcopyrite* ($CuFeS_2$), or copper pyrites, which is in reality a sulphide of iron and coppes combined, the proportion varying from an exceedingly cupriferous variety (chalcopyrite) to pure iron pyrites." The sulphide of copper known as copper pyrites is a definite chemical compound, with proportions of iron and copper in a definitely fixed ratio, so that the mineral cannot vary from an exceedingly cupriferous variety to pure iron pyrites. The same may also be said of other sulphides of copper.

Copper pyrites is often, and even usually, when found in nature, mechanically mixed with iron pyrites, and the relative amounts of copper pyrites and iron pyrites in a deposit may vary considerably. Different analyses of this mixture of the two minerals may, therefore, show varying proportions of copper and iron, but the composition of the copper pyrites itself is constant.

On page 23 the author speaks of the "pale yellow rust" of lead ores, and by "rust" he means doubtless the carbonate of lead formed by the action of surface agencies on the superficial parts of certain lead deposits. This product is often stained yellow or brown by the oxidation of iron pyrites, which is frequently associated with galena, the common ore of lead; but the normal color of the "rust," or carbonate of lead, is white. An oxide of lead of a yellow color may be formed when certain lead minerals are highly heated under suitable conditions, but this process would obviously be a very unusual one in nature, and the common product of the superficial alteration of galena ores is first the sulphate and then the carbonate of lead.

On page 132 the author, in speaking of iron ores, says: "The carbonate, siderite, may be considered to be a combination of iron and calcite in which the percentage of iron varies even to the point of complete replacement of the calcium." Siderite is a definite chemical compound containing iron protoxide and carbonic dioxide in fixed proportions, while calcite is also a definite chemical compound containing calcium oxide and carbonic dioxide in fixed proportions. Both siderite and calcite are isomorphous carbonates, and the two crystallize together in various proportions. The carbonate of iron, however, can in no way be called a "combination of iron and calcite."

The Lake Superior copper and iron districts, which, taken together, form one of the most important mining regions in the world, are discussed very briefly, but even the descriptions given are inaccurate. On page 210, in speaking of the Lake Superior copper ores, the author says that "in some of the mines, mineralized ores of copper are the source of the metal, but the most common ore is native copper frequently associated with native silver." The fact is that none of the copper produced in the Lake Superior region is derived from "mineralized"[1] ores of copper, but all of it is obtained from native copper. The native copper is sometimes slightly stained green by the forma-

[1] By "mineralized ores" it is supposed that the author means the ores in which the copper is combined with other elements, forming sulphides, carbonates, oxides, etc.

tion of a thin crust of carbonate of copper on its surface, but even this does not always happen, and one of the remarkable features of the Lake Superior region is the very extensive occurrence of copper in its native state. Copper sulphides are disseminated through the region, and are probably the source from which the native copper was derived in nature; but they have not been found to be themselves concentrated in commercially important quantities, and are therefore not mined. Small quantities of oxide of copper also occur, but are likewise not of present importance.

On page 125 Professor Tarr, in describing a section by Van Hise, showing the mode of occurrence and formation of the iron deposits in the Penokee-Gogebic range in the Lake Superior region, states that Irving and Van Hise have shown that the hematite deposits of that region were formed by a replacement of "beds of dolomitic limestone." It may be said here that the iron deposits of the Penokee-Gogebic range occur in the Upper Huronian series, which, in this district, contains no dolomitic limestones. A dolomitic limestone occurs near the base of the Lower Huronian of the district, but it has no connection whatsoever with the Penokee-Gogebic iron deposits. Van Hise clearly states, in his various publications on this subject, that the iron deposits of the Penokee-Gogebic range represent a replacement of a siliceous rock containing carbonate of iron and other carbonates, and designated by him as cherty iron carbonate. One of the principal points which Van Hise brings out in the discussion of his theory for the formation of these deposits is that the change has been largely an oxidation of the iron carbonate and a replacement of silica by oxide of iron. Professor Tarr also gives a geological section illustrating the occurrence of the Penokee-Gogebic ores, and designated by him as "modified from Irving and Van Hise." In the legend below the section, the iron deposits are referred to as "iron ore, replacing ferruginous chert"—a statement not at all in accord with Professor Tarr's text just cited. It is, moreover, difficult to understand on what basis an author, who has never studied a region, has "modified" the geological sections of other authors who have spent years in investigating that region.

The errors in this book that have already been pointed out are only a few among the many that might be mentioned, but they serve to show the want of familiarity with the subject and the inaccuracies prevalent throughout the volume.

In a work of this kind, brief and concise statements are necessary in order to confine the volume to its proper size, but the different subjects should receive discussion more or less briefly according to their importance, and the more important subjects should not be neglected while the less important are treated in detail. The latter course not only prevents a book from containing as much useful information as it might otherwise do, but it also makes it extremely misleading to the student, for it gives him an erroneous idea of the relative importance of the different branches of the subject. Thus, in the present volume, the discussion of iron covers 27 pages. Of this number only 18 pages are given to the description of iron deposits proper, while nine pages are given to the enumeration of statistics which might have been condensed into a third of that space. Moreover, the great iron region of the Lake Superior country, which supplies more than two-thirds of the iron ore used in the United States, receives only three pages of treatment. The copper region of the Lake Superior country receives only four pages, and the copper and silver region of Butte City, Montana, one of the most celebrated mining localities in the world, receives only two pages; while other much less important subjects receive many pages. Such inequalities might be justifiable if the geology of certain regions were so simple that it could be described in a few words, even though the commercial features might be of great importance. In the instances cited, however, this is not the case.

Economic geology, including both the subject of ore deposits and other subjects which properly belong to this branch of geology, is in much need of accurate geological work and careful discussion. This is especially true in the United States, which is preëminently the mining region of the world; and it is unfortunate that a treatise relating mostly to the ore deposits of this country should have failed to give the subject thorough treatment. The volume, though in some parts it need not be severely criticised, shows in most parts an extremely superficial knowledge of economic geology, and contains many the errors in statements regarding the mineralogical nature of ores and geological nature of ore deposits; it shows a want of knowledge of the commercial features of the various mining industries, and it bears evidence of a lack of the sense of proportion in the amount of space given to different subjects.

R. A. F. Penrose, Jr.

The Canadian Ice Age. Notes on the Pleistocene Geology of Canada, with Especial Reference to the Life of the Period and its Climatal Conditions. By SIR J. WILLIAM DAWSON, G.M.G., LL.D., F.R.S., F.G.S., etc. Montreal: William V. Dawson, 1893. 301 pp., 8vo.

The work opens with a chapter of historical notices, embracing a sketch of the tenets held by the author during the long period of his studies on Pleistocene phenomena. Among these are the following: 1. The phenomena are not to be explained by any one cause, or by any one all-embracing hypothesis. 2. The astronomical changes that have been invoked are incapable of fully explaining the facts. 3. There has not been, at any time, a polar ice cap. 4. The phenomena indicate local mountain glaciers coöperating with floating ice in various forms. 5. The cold climate was mainly the result of peculiar geographical conditions and of a different distribution of oceanic currents. 6. The close of the period was not very remote. The author quotes freely from his previous writings in elucidation of these views, and cites certain recent tendencies that seem to him to indicate a drift of opinion towards the views he has held so long.

In the second chapter he gives the succession of Pleistocene deposits in Canada, as he correlates them, as follows:

Montreal and Lower St. Lawrence. J. Wm. Dawson.	*North Shore of Lake Ontario.* J. G. Hinde.	*Belly River, Northwest Territory.* G. M. Dawson.
I. Surface soil, post-glacial alluvia, and peat.	I. Surface soil, stratified sand and gravel.	I. Surface soil and prairie alluvium.
II. Surface boulders, Saxicava sand and gravel. Boulders in and below sand.	II. Boulders, sand, etc. Laminated clay. Upper boulder deposit.	II. Upper boulder clay.
III. Upper Leda clay, marine shells and drift plants. Lower Leda clay, marine shells and drift plants.	III. Stratified sand and clay, with fresh-water shells and plants.	III. Gray sand with iron-stone nodules. Brownish sandy clay. Carbonaceous layers and peat. Gray sand iron-stone.
IV. Lower boulder clay or till. Many native and some traveled boulders. A few marine shells of arctic species.	IV. Lower boulder clay or till. Native and traveled boulders.	IV. Lower boulder clay. Many traveled boulders.

This is followed by a general view of the entire series of deposits of eastern Canada and a discussion of these, in the course of which he states the views of the origin of the deposits which are set forth more fully in a subsequent part of the book. In the course of the chapter he presents a scheme of correlation of the phenomena of the glacial period in the Cordilleran region conjointly with those of the region of the great plains (in ascending order), in which epeirogenic movements constitute the leading feature. The following is an abbreviation:

Cordilleran Region.	*Region of the Great Plains.*
Cordilleran zone at a high elevation; severe glaciation; maximum development of Cordilleran glacier.	Correlative subsidence and submergence of the great plains with possible contemporaneous elevation of Laurentian axis and maximum development of the ice upon it.
Gradual subsidence of Cordilleran region; boulder clay of interior plateau and Yukon basin; lower boulder clay of coast region; interglacial silty beds at later stage.	Correlative elevation of western part of great plains, probably irregular; formation of extensive lakes; interglacial deposits, including peat beds.
Re-elevation of Cordilleran region; maximum of second glaciation.	Correlative subsidence of plains; submergence to base of Rocky Mountains; formation second boulder clay.
Partial subsidence Cordilleran region; formation of white silts; upper boulder clay of coast region, probably.	Correlative elevation of plains, probable formation of Missouri Coteau along shore line.
Renewed elevation of Cordilleran region; general amelioration, closing glacial period.	Simultaneous elevation of great plains to present levels; exclusion of the sea; formation of Lake Agassiz; gradation into present period.

Sir William Dawson would make three subdivisions of the Pleistocene period embracing (*a*) *Earlier Pleistocene;* irregular depression of the continents, with cold climate and great local glaciers; (*b*) *Middle Pleistocene;* submergence of coasts and re-elevation of interior plateaus, with milder climate—interglacial period; and (*c*) *Later Pleistocene;* submergence of plains and general ice drift with local glaciers in mountains. The succeeding thirty pages of the chapter are devoted to the description of the deposits.

The third chapter is devoted to physical and climatal conditions. In the course of this the author introduces a map to show the distribution of glaciated and unglaciated land, and of ice-laden and of ice-free

water during a typical stage of the Pleistocene period. Greenland, the Laurentian tract, the Adirondack, the northern Appalachian, and the northern Cordilleran regions are represented as glacial land. A broad tract sweeping around the Laurentian belt covering the Great Lake region and a large portion of the great plains of Canada is represented as submerged beneath an ice-laden sea. So also is a large area embracing Hudson's Bay and the adjacent straits. The Central American region is represented as extensively submerged and the equatorial waters of the Atlantic are represented as passing through to the Pacific.

Under the head of causes of glaciation, the author rejects with emphasis the prevalent glacial hypothesis, insisting strongly upon the impossibility of so great an ice sheet reaching to so low a latitude. He quotes extensively from Woeickoff in support of his position. The terminal moraines of most American writers he refers to deposition "at the margin of a sea laden with vast fields of floating ice," and thinks that some of the anomalies in their levels are due to differential elevation. He explains the striation (in regions not occupied by glaciers, under his view) by referring them largely to the action of "pan ice" aided by tides, especially on sinking coasts, and subordinately to iceberg action proper. His views on this point are well known. The very peculiar climatic conditions of the age are attributed to geographical changes, but the discussion is not carried into detail, and we have been unable to form a definite conception of the supposed method of causation.

The most valuable chapter, in our judgment, is that which relates to Pleistocene fossils. There is an admirable collection of data in detail, especially from the Lower St. Lawrence region—the richest of American fields in glacial paleontology. In regard to the relations of man to the glacial formations, Sir William Dawson apparently inclines to the interpretations of Professor Holmes.

At the close of the work complimentary reference is made to Howorth's book, "The Glacial Nightmare," and the similarity of views there expressed to those of the present work approvingly noted. Tactically we think this is an error, since conclusions associated with field experience such as those of Dr. Dawson will be likely to be placed by geologists in quite a different category from the dialectic lucubrations of a mere academic treatment. Support must be scant when "The Glacial Nightmare" is counted in.

The present writer dissents radically from the author's fundamental conclusions and from his estimate of the present drift of opinion, but finds the book interesting and suggestive, and its contributions to Pleistocene paleontology notably valuable. T. C. CHAMBERLIN.

The Post-Pliocene Diastrophism of the Coast of Southern California. By ANDREW C. LAWSON. Bulletin of the Department of Geology, University of California Vol. 1, No. 4, pp. 115–160, plates 8–9.

IN this bulletin, Professor Lawson presents the results of some of his studies on the west coast of California. The essay concerns itself especially 1° with the coasts of San Diego and Los Angeles counties, and with the islands of San Clemente and Santa Catalina which lie a few miles to the west; and 2° with the coastal region from Santa Cruz to the Golden Gate. So far as concerns the southern region, the data are drawn principally from four localities. These are: a) the coastal slope of San Diego county,—the San Diego mesa; b) San Pedro Hill; c) San Clemente Island; d) Santa Catalina Island.

The San Diego mesa is a terraced plain having a breadth of from twelve to eighteen miles. It is characterized as a Pliocene delta, made up principally of Pliocene sands and sandstones, but covered by a thin sheet of river gravels. The evidence for the statement that these gravels are of fluviatile origin is not given. The gravels are thought to have been deposited approximately at sea level. They now stand at a maximum elevation of nearly eight hundred feet. The inference is that an elevation of eight hundred feet has taken place along the coast of San Diego county since Pliocene time. Various marine terraces at levels of seven hundred feet and less characterize the mesa.

San Pedro Hill is an abrupt headland on the coast of Los Angeles county. Its slopes likewise show a series of marine terraces and sea-cliffs. The highest terrace on this headland stands at an elevation of 1240 feet. There are many lower terraces on the San Pedro Hill, the lowest mentioned having an altitude of 120 feet. Through the higher terraces the streams have cut for themselves cañons; but they flow over the lower terraces in shallow channels. This is evidence of the recency of the elevation marked by the lower terraces. Molluscan borings in the old sea-cliffs, up to an elevation of 1240 feet, may still be seen.

From the relations of the Miocene to the Pliocene formations of the headland, it is inferred there was an "important interval of denu-

dation between the Miocene uplift and the depression which permitted the deposition on the lower flanks of the hill of the formations which paleontclogists recognize as of Pliocene age. The recovery from this Pliocene depression is the uplift which is registered in the elevated strands of the hill." The uplift following the Pliocene depression is regarded as Pleistocene. This conclusion is of course warranted, if the Pliocene strata involved are known to belong to the closing stages of the Pliocene period. Otherwise it does not appear that the conclusion is a necessary one. Pleistocene strata are referred to as overlying the Pliocene, and as belonging to a recent stage of the uplift. Between the Pliocene and the Pleistocene no evidence of subaërial denudation exists.

On the west side of San Clemente Island seventeen well marked terraces occur, the highest at an elevation of 1320 feet. These terraces are from 200 to 1500 feet in width. There are less distinct terraces up to a height of 1500 feet. "The total amount of horizontal sawing which has been effected on the slopes of the island by wave action during its elevation through the last 1320 feet," is more than two miles.

Santa Catalina Island is of about the same size, trend, and height as San Clemente. It has a position midway between San Pedro Hill and San Clemente; but on Santa Catalina "there is no trace of an elevated wave-cut terrace, sea-cliff, or strand line of any kind observable." Furthermore, "The stream topography of the island is very much more advanced, *i. e.*, much more ancient than that of either San Pedro Hill or San Clemente."

The absence of terraces and sea-cliffs cannot be attributed to the character of the rock, and their absence is in harmony with the condition of the stream valleys, which indicate that the island has not been below the sea in recent times; that is, "Santa Catalina has not been subjected to the uplift which has affected the two prominent insular masses, one twenty-five miles to the north of it, and the other twenty-five miles to the south of it." Not only has Santa Catalina not been elevated while San Pedro and San Clemente were undergoing the great uplifts which have been mentioned, but it is believed to have actually sunk while these other land masses were being lifted. The evidence of sinking is found in the drowned valleys of certain parts of the coast, and in the falls and rapids which mark the termini of the streams of other parts. Santa Catalina would appear to be situated in

the trough of a syncline which has been actually sinking while the lands on either side were rising.

The coast of the Bay of Monterey is also marked by a series of terraces. Four of them, the highest of which reaches an elevation of 712 feet, are very distinct, and abut against sea-cliffs. Higher terraces extend up to an elevation of 1201 feet. The river valleys also of the Santa Cruz region are found to afford evidence in harmony with that already cited from the regions further south. The general tenor of the evidence presented by this part of the coast is therefore in harmony with that presented by the more southerly region. Here also there has been a marked epeirogenic movement in recent times.

On the peninsula of San Francisco, marine Pliocene rocks, having a thickness of more than one mile, are said to exist. It is believed that subsidence accompanied the accumulation of this great series. These strata now occur at an elevation of over 700 feet. Not only this, but the strata have been so tilted, and subsequent erosion has been so great, that the base of the series, as well as the top, is exposed at this elevation. The elevation is said to have been post-Pliocene. Of course this is true, if the uppermost Pliocene strata involved represent the close of the Pliocene period.

According to the author, the relations of the Pliocene strata indicate great orogenic as well as epeirogenic movements in this region since their deposition. Montara Mountain is believed to have been produced during the orogenic event by which the Pliocene rocks (Merced series) were lifted into their present position. The granite axis of the mountain is regarded as the up-thrust base on which the Pliocene strata were laid down. All the adjacent younger strata dip away from this granite axis quaquaversally. While, therefore, the general structure of the mountain is comparable to that of a laccolite, it is, according to Professor Lawson, very different from it genetically.

On the basis of the facts given in the paper, there would appear to be no ground for doubt concerning the main conclusions at which Professor Lawson arrives concerning the movements of the coast in recent times. On the basis of evidence presented, there might be some question as to the post-Pliocene date of all these changes of level, did not Professor Lawson define the Pleistocene so as to include them. He says (p. 159), "It is not an easy matter to delimit the Pliocene and Pleistocene epochs so that they shall correspond to the same divisions of the geological scale in the eastern part of the continent. . . . . The rea-

son for this is that there has been no distinct break in the continuity of marine conditions throughout the epochs, only a gradual transition of conditions. In this gradual transition there was, however, a reversal of the epeirogenic movement of the coast from a process of depression to a process of uplift. This turning point of the disastrophic pendulum . . . . is believed to correspond well with the beginning of the Pleistocene." With this definition of the Pleistocene, of which we are not disposed to complain, there can be no doubt as to the age of the remarkable changes of level which Professor Lawson describes. It is to be hoped that at some future day he may give us an account of the corresponding phenomena along a greater and connected stretch of the California coast. The results announced in this paper purport to be no more than the results of a general reconnaissance of the regions described.

ROLLIN D. SALISBURY.

Analytical Abstracts of Current Literature.

Ein typisches Fjordthal. von Erich von Drygalski. z. Z. Grönland. 14 pp.

Dr. Drygalski describes in detail a valley on the west coast of Greenland, one peculiarity of which is that there are three considerable depressions along its axis. These are occupied by lakes, some of which certainly, and all of which probably, have rock basins. Another peculiarity of the valley is that it crosses a narrow highland between two fjords. One end lies at the sea level, the other 211 m. above it, the slight drainage through the valley having a fall of this amount at the end of the valley. This latter point is nearly 100 m. below the divide in the valley, from which drainage flows in opposite directions. The valley is about 5½ km. long, about 1 km. wide, and has an average depth of about 336 m. While the valley is well above sea level, and therefore no fjord, it is pointed out that, with a relatively higher sea, it would become a fairly typical fjord. In the judgment of the author, the situation is such as to preclude the idea that the valley is a river valley, or that it is a river valley modified by ice action, and the author is "very much inclined to extend this conclusion to the fjords" he has seen. Dr. Drygalski advocates the view that this valley owes its origin primarily to the weathering of the gneiss in which it lies, and suggests that joint-planes, by determining the position of greatest weathering, determined also the position of the valley. Subsequently, after the valley had come into existence by weathering, the ice removed the weathered products, and an undetermined depth of solid rock below. The author leaves it to be understood that this is, in his judgment, a principal, if not the principal method by which the fjords with which he is familiar have originated. R. D. S.

A Preliminary Report on the Cretaceous and Tertiary Formations of New Jersey. By William Bullock Clark, Annual Report of the State Geologist of New Jersey, 1892.

This report presents the results of investigation conducted by Professor Clark and his assistants during the year 1892 upon the coastal plain formations of New Jersey. The report, with a new geological map, covers the area of the U. S. Geological Survey atlas sheets of New Brunswick and Sandy

Hook. The text contains an historical sketch in which the work of past investigators is briefly cited, and reference made to the various views upon the classification and correlation of the several formations. A second chapter is devoted to a consideration of the physical features of the coastal plain, following which is an extended statement in regard to the stratigraphical characteristics of the formations found there. Although an attempt is made to make the classification of the deposits coincide, so far as it is possible, with the investigations of the late Professor Cook, yet some changes of importance are considered to be necessary. The name Raritan formation is proposed in place of the wholly inadequate term Plastic Clay, and the Upper Marl bed, which is in part Cretaceous and in part Eocene, is divided into Manasquan Marl and Shark River Marl respectively. The division of Yellow Sand proposed by Professor Cook is not held to be an independent formation, but is included under the Manasquan Marl. The Miocene is considered to be extensively developed in New Jersey. Although fossils have been found at only a few points, they are thought to be sufficient in number to indicate a series of deposits several hundred feet in thickness and many square miles in surface exposure.

In summing up his statements in regard to the relation of the several formations, Professor Clark says, "the deposits of the coastal series of New Jersey show complete conformity from the bottom of the Raritan formation to the top of the Upper Marl bed, while no wide-reaching dislocations of the strata have been observed at any point. The strike follows a nearly continuous trend of N. 50 E., while the dip is twenty-five to thirty feet in the mile to the southeast. Overlying the Upper Marl bed unconformably is the Miocene, which possesses the same general structural and stratigraphical features as the earlier members of the series."

The origin of greensand, which characterizes so many of the coastal plain formations of New Jersey, is fully considered, the results by Professors Murray and Renard, of the Challenger Expedition, being given with much fullness. The geological distribution of greensand is briefly reviewed, and the character of the New Jersey deposits more fully considered. Three colored plates are reproduced from the Challenger Expedition report on Deep-Sea Deposits, to illustrate the mode of formation of glauconite. R. D. S.

The Pleistocene Rock Gorges of Northwestern Illinois. By OSCAR H. HERSHEY. American Geologist, November, 1893.

The object of this paper is to ascertain the length of the "deglaciation interval and perhaps interglacial epoch." The ice of the maximum period of glaciation affected this region but slightly. In some cases the glacial sand and gravels were deposited in ridges transverse to the streams' courses, thus damming the streams and producing small lakes. Sometimes the barriers were so

high that the course of drainage was altered. The new valleys were cut in Galena limestone. The amount of cutting in the limestone since maximum glaciation is about equal to that in the newer drift in the vicinity of Lake Michigan. The later work has been going on, it is believed, about 7000 years. It is estimated that erosion in the limestone of northwestern Illinois took place one tenth as fast as in the drift. On this basis 70,000 years have been required for the erosion accomplished in northwestern Illinois since the maximum period of glaciation. Long after the withdrawal of the maximum ice-sheet, a mantle of loess was spread over northwestern Illinois. The writer thinks that something like four fifths of the erosion accomplished since the withdrawal of the maximum ice-sheet was accomplished before the deposition of the loess. Fifty thousand years are considered a minimum, and perhaps twice that time not too great an allowance of time, for the erosion that took place between the time of the formation of the drift sheet in northwestern Illinois and the deposition of the loess. J. A. B.

Notes on the Sea-Dikes of the Netherlands. By PROF. J. C. SMOCK. (Annual Report of the State Geologist of New Jersey, 1892, pp. 315–329).

These notes are descriptive of the dikes at the Helder and at Petten in North Holland, and at West Kappele in Zealand. The breaks in the coastal dune ranges are occupied by them. The whole sea-front is protected by a system of jetties also. They are built on the strand and in front of the dikes—and check the currents which carry away the beach sands and tend to undermine the dune hills at these localities. The dikes are essentially enormously thick walls of sand whose outer slope is at a low angle, and is faced with stone and further protected by rip-rap and by piling. The descriptive notes of the construction are illustrated with plans and vertical cross-sections.

The application of a modified system of sea-dikes for the protection of the bluffs at Long Branch, New Jersey, follows. The reclamation of the tidal lands of the state is referred to, and the reclamation of the low-lands of Holland affords an instructive example.

J. C. S.

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